United States
Environmental
Protection Agency

Office of Water
(4601)

EPA 815-D-03-004
July 2003
Draft

STAGE 2 DISINFECTANTS AND DISINFECTION BYPRODUCTS RULE

SIGNIFICANT EXCURSION GUIDANCE MANUAL

This text is a draft provided for public comment. It has not had a final review for technical accuracy or adherence to EPA policy; do not quote or cite except as a public comment.

Note on the Stage 2 Disinfectants and Disinfection Byproducts Significant Excursion Guidance Manual, July 2003 Draft

Purpose:

The purpose of this guidance manual, when finalized, is solely to provide technical information for water systems and States to use for identifying and reducing significant excursions of DBP levels. The Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR) contains a provision for significant excursions. EPA is developing the Stage 2 DBPR to reduce DBP occurrence peaks in the distribution system based on changes to compliance monitoring provisions.

This guidance is not a substitute for applicable legal requirements, nor is it a regulation itself. Thus, it does not impose legally-binding requirements on any party, including EPA, states, or the regulated community. Interested parties are free to raise questions and objections to the guidance and the appropriateness of using it in a particular situation. Although this manual describes many methods for complying with significant excursion requirements, the guidance presented here may not be appropriate for all situations, and alternative approaches may provide satisfactory performance. The mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Authorship:

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Request for comments:

EPA is releasing this manual in draft form in order to solicit public review and comment. The Agency would appreciate comments on the content and organization of technical information presented in this manual. Please submit any comments no later than 90 days after publication of the Stage 2 Disinfectants and Disinfection Byproducts Rule proposal in the *Federal Register*. Detailed procedures for submitting comments are stated below.

Procedures for submitting comments:

Comments on this draft guidance manual should be submitted to EPA's Water Docket. You may submit comments electronically, by mail, or through hand delivery/courier.

- To submit comments using EPA's electronic public docket, go directly to EPA Dockets at http://www.epa.gov/edocket, and follow the online instructions for submitting comments. Once in the system, select "search," and then key in Docket ID No. OW-2002-0039.

- To submit comments by e-mail, send comments to OW_Docket@epa.gov, Attention Docket ID No. OW-2002-0043. If you send an e-mail comment directly to the Docket without going through EPA's electronic public docket, EPA's e-mail system automatically captures your e-mail address, which is included as part of the comment that is placed in the official public docket.

- To submit comments on a disk or CD ROM, mail it to the address identified below. These electronic submissions will be accepted in WordPerfect or ASCII file format. Avoid the use of special characters and any form of encryption.

- To submit comments by mail, send three copies of your comments and any enclosures to: Water Docket, Environmental Protection Agency, Mail Code 4101T, 1200 Pennsylvania Ave., NW, Washington, DC, 20460, Attention Docket ID No. OW-2002-0043.

- To submit comments by hand delivery or courier, deliver your comments to: Water Docket, EPA Docket Center, Environmental Protection Agency, Room B102, 1301 Constitution Ave., NW, Washington, DC, Attention Docket ID No. OW-2002-0043.

Please identify the appropriate docket identification number in the subject line on the first page of your comment. If you submit an electronic comment, please include your name, mailing address, and an e-mail address or other contact information in the body of your comment. Also include this contact information on the outside of any disk or CD ROM you submit, and in any cover letter accompanying the disk or CD ROM.

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Tables

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Acronyms

CFD	Computational Fluid Dynamic
CFR	Code of Federal Regulations
CT	Disinfectant residual × contact time
DBP	Disinfection Byproduct
DOC	Dissolved Organic Carbon
EPA	Environmental Protection Agency
FACA	Federal Advisory Committees Act
GAC	Granular Activated Carbon
HAA5	Haloacetic Acids [total of five]
HPC	Heterotrophic Plate Count
IDSE	Initial Distribution System Evaluation
IESWTR	Interim Enhanced Surface Water Treatment Rule
LRAA	Locational Running Annual Average
LT1ESWTR	Long Term 1 Enhanced Surface Water Treatment Rule
MCL	Maximum Contaminant Level
M-DBP	Microbial-Disinfectants/Disinfection Byproduct
MG	Milligrams
MGD	Million Gallons per Day
NOM	Natural Organic Matter
QA/QC	Quality Assurance/Quality Control
SCADA	Supervisory Control and Data Acquisition
Stage 2 DBPR	Stage 2 Disinfectants and Disinfection Byproducts Rule
SWTR	Surface Water Treatment Rule
THM	Trihalomethane
TOC	Total Organic Carbon
TTHM	Total Trihalomethanes

1.0 Introduction

The Stage 2 Microbial-Disinfection Byproducts (M/DBP) Agreement in Principle acknowledges that significant excursions of DBP levels will sometimes occur, even when systems are in full compliance with the enforceable Maximum Contaminant Level (MCL). EPA has developed this manual to give guidance to States and public water systems on identifying significant excursions and how to conduct peak excursion evaluations and reduce such peaks. The specific objectives of this manual are to:

- Define significant DBP excursions
- Summarize requirements for addressing significant excursions
- Provide a methodology for identifying the cause of significant excursions
- Provide guidance for documenting significant excursions
- Present the options available to reduce DBP concentrations in the distribution system
- List additional references

1.1 What is a Significant DBP Excursion?

The Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR), under Stage 2B, requires systems to meet a running annual average of 80 µg/L for total trihalomethanes (TTHM), and 60 µg/L for haloacetic acids (HAA5) at each monitoring location in the distribution system (40 CFR 141, Subpart Q, Appendix A). Because the individual samples are averaged over one year to determine compliance with the Stage 2 DBPR, the DBP levels at a given location can fluctuate throughout the year. This is normal and generally the result of seasonal changes in water temperature and/or organic content.

States must define the criteria for determining that a significant DBP excursion has occurred as a special primacy condition of the Stage 2 DBPR (40 CFR 142.16). One approach a State might use in identifying a significant excursion is to define a maximum concentration that, if exceeded, would require an evaluation. For example, a State may define a significant DBP excursion as any compliance sample that exceeds the following:

- TTHM concentration of 100 µg/L
- HAA5 concentration of 75 µg/L

Another approach a State may take to defining a significant DBP excursion is to compare results from individual quarterly measurement from compliance monitoring with the LRAAs computed for that period. Using 40 µg/L for TTHM and 30 µg/L for HAA5 as a benchmark, a significant excursion occurrs under the following conditions:

- For TTHM, the difference between a quarterly location measurement and the quarterly LRAA is > 30 µg/L <u>and</u> the LRAA is $ 40 µg/L for TTHM a significant excursion has occurred.

- For HAA5, the difference between a quarterly location measurement and the quarterly LRAA is > 25 µg/L <u>and</u> the LRAA is $40 µg/L for TTHM

EPA developed this approach based on analyses of data collected under the Information Collection Rule (ICR). The following example illustrates how a significant excursion is identified with the "difference approach."

Example - Significant Excursion Occurrence Identified by the Difference Approach

Your system is required to monitor at 4 SMP locations. During the last sampling period which took place in June 2004, your city experienced higher HAA5 values relative to the LRAA at one monitoring location (#4). DBP data from the previous year and most recent sampling period (five quarters total) are presented in the table below.

Example TTHM and HAA5 Monitoring Data

	TTHM (ug/L)			HAA5 (ug/L)		
Locations	LRAA Pre-June 2004 Avg.	June 2004 Data	LRAA June 2004 Avg.	LRAA Pre-June 2004 Avg.	June 2004 Data	LRAA June 2004 Avg.
#1	65	63	67	40	52	40
#2	63	72	64	**<u>33</u>**	**<u>59</u>**	38
#3	64	81	68	43	51	46
#4	49	79	66	40	84	50

[1]Data for sampling conducted on June 2004, September 2004, March 2004, and December 2003. Data relevant to peak excursions are **<u>bold and underlined</u>**.

Data for June 2004 at location #2 meet the criteria of significant excursion. Specifically, the significant excursion was identified using the following two-step procedure:

<u>Monitoring location #2 (HAA5 Significant Excursion):</u>

Step 1: Is the quarterly pre-June 2004 LRAA (HAA5) >30 µg/L?
If yes a significant excursion is possible.

The quarterly Pre-June 2004 LRAA (HAA5) is 33 μg/L (see Table 1-1) and is greater then 25 μg/L, thus a significant excursion is possible (see definition of significant excursion in section 1.1).

Step 2: Is the difference between the quarterly location measurement for HAA5 and quarterly pre-June 2004 LRAA (HAA5) > 25 μg/L?
If yes a significant excursion has occurred.

Quarterly location measurement is 59 μg/L and the quarterly Pre-June 2004 LRAA (HAA5) is 33 μg/L (see data in table).

59 - 33 μg/L = 26 μg/L.

The difference between quarterly location measurement and quarterly Pre-June 2004 LRAA is greater than 25 μg/L, thus a significant excursion has occurred (see definition of significant excursion in section 1.1).

1.2 What Should Systems do to Address Significant Excursions?

A significant excursion, as defined above, is not a violation of the Stage 2 DBPR and does not require any public notification or reporting as significant excursions or violations in your Consumer Confidence Reports. Reducing DBP concentrations is a primary objective of the Stage 2 DBPR and is an important goal in providing quality drinking water. Chapter 4 of this guidance manual suggests operational improvements, alternative disinfection strategies, and DBP precursor removal technologies that can be used to reduce DBP concentrations.

The Stage 2 DBPR does require you to:

1) Evaluate distribution system operational practices to identify opportunities to reduce DBP levels (such as tank management and to reduce residence time and flushing programs to reduce disinfectant demand).

2) Review the evaluation with your State no later than the next sanitary survey.

Because it may be a few years between the significant excursion and your next sanitary survey, EPA strongly encourages systems to take immediate steps to identify and document the cause of the excursion.

1.3 Organization of this Guidance Manual

This guidance manual is organized as follows:

- Chapter 1 - Introduction: Presents the Stage 2 DBPR requirements for addressing significant DBP excursions.

- Chapter 2 - Causes of Significant DBP Excursions: Identifies the most common causes of significant DBP excursions.

- Chapter 3 - Identifying the Cause Of and Documenting Your DBP Significant Peak Excursion: Provides a template for documenting a significant excursion in addition to guidance for identifying the cause.

- Chapter 4 - Best Management Practices and Distribution System Improvements to Reduce DBP Concentrations: Summarizes the options available to reduce DBP significant concentrations, including operational changes and distribution system modifications.

- Chapter 5 - References

Appendix A discusses the fundamentals of DBP formation. Appendices B through E are examples of completed evaluation reports compiled when the significant excursion is identified using the "maximum concentration approach" (> 100 µg/L for TTHMs and > 75 µg/L for HAA5). Appendice F is an examples of completed evaluation reports compiled when the significant excursion is identified using the "difference approach."

2.0 Causes of Significant DBP Excursions

Significant excursions typically occur as a result of changes in source water quality, changes in treatment plant operations or as a result of distribution system characteristics or changes that impact DPB levels. This chapter discusses each of these causes, and is organized as follows:

2.1 Fundamentals of DBP Formation
2.2 Impacts of Changes in Source Water Quality on DBP Concentrations
2.3 Impacts of Changes in Treatment Plant Operations on DBP Concentrations
2.4 Impacts of Distribution System Characteristics on DBP Concentrations

Chapter 3 follows with a guide to identifying causes of specific DBP excursion events.

2.1 Fundamentals of DBP Formation

TTHM and HAA5 are primarily formed by the reaction of chlorine or chloramines with natural organic matter (NOM). The amount of TTHM and HAA5 formed is impacted by a number of occurrences including the following factors:

- NOM concentration
- NOM characteristics
- Chlorine or chloramine concentration
- Concentration of other DBP precursors (e.g., bromide)
- pH
- Temperature
- Reaction time (contact time)

The following sections discuss how each of these factors affects the formation of TTHM and HAA5 and how changes in these parameters may result in increases in TTHM and HAA5 concentrations. Greater detail regarding the formation of TTHM and HAA5 is provided in Appendix A.

2.2 Impacts of Changes in Source Water Quality on DBP Concentrations

Changes in source water quality that affect the reaction between NOM and chlorine or chloramines can increase TTHM and HAA5 concentrations. Typically, changes that increase TTHM and HAA5 concentrations include the following occurrences:

- Increase in source water NOM
- Increase in source water temperature
- Increase in source water bromide concentration
- Changes in NOM characteristics
- Changes in other source water characteristics (e.g., pH or alkalinity)
- Change in source of water supply

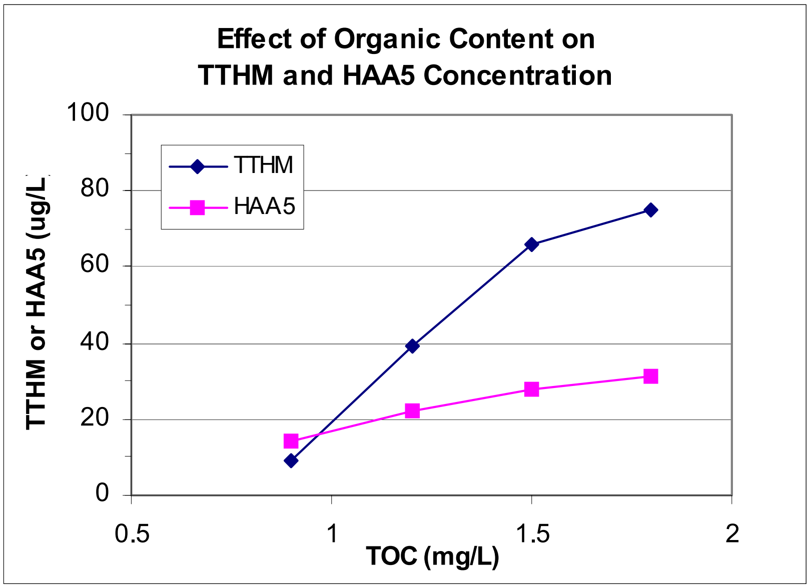
2.2.1 Increase in Source Water NOM

NOM is a precursor to the formation of TTHM and HAA5. Therefore, increases in the source water NOM concentration not addressed by adjustments in the treatment process can lead to increased formation of TTHM and HAA5 both in the plant and in the distribution system.

Surface water sources may have increases in organic matter following periods of heavy rainfall which causes greater surface water runoff. These events do not need to occur locally to result in an increase in NOM. A rainfall event miles upstream from a raw water intake can result in increased NOM concentrations. Other causes of increased NOM concentrations include lake or reservoir turnover, river scour, and point source pollution (e.g., wastewater treatment plant discharges, filter backwash or other discharges from upstream water treatment plants, and industrial discharges). Some plant operation changes can cause increases in source water NOM (e.g., inadequate sludge removal in pre-sedimentation or sedimentation basins).

Figure 2.1 shows the effect of NOM concentration (measured as total organic carbon [TOC]) and time on TTHM and HAA5 concentrations. As NOM concentration increases, both TTHM and HAA5 concentrations also increase.

Figure 2.1 Effect of NOM Concentration on TTHM and HAA5 Concentration
(chlorine dose 4.3 mg/L)



Source: A. Franchi and C. Hill (2002).

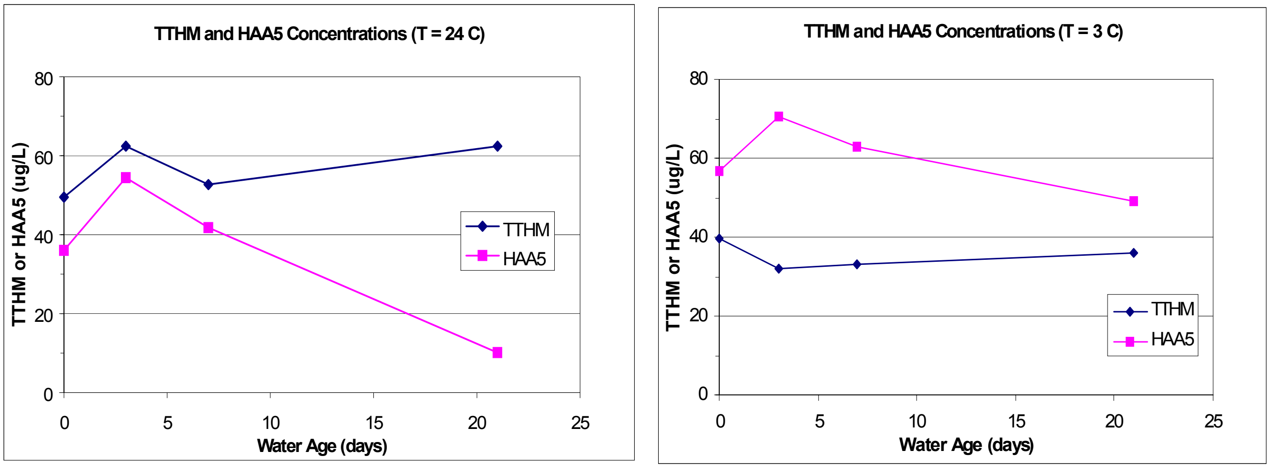
2.2.1 Increase in Source Water Temperature

The rate of reaction between chlorine (and chloramines) and NOM increases as the water temperature increases. As a result, TTHM and HAA5 concentrations can be higher during periods of warmer source water temperatures. Most water supplies experience seasonal temperature changes with higher temperatures in the summer and early fall and lower temperatures in the winter and early spring. The magnitude of the increase is dependent on a number of -specific factors, including source water type (ground or surface water), climate, and hydrology.

Surface water temperatures are normally impacted by ambient temperatures and other environmental factors, such as rainfall and snow melt, while ground water temperatures generally exhibit less seasonal variability. Raw water storage can also effect the source water temperature. Specifically, long holding times in raw water storage basins in summer months can significantly increase temperatures.

Water temperature can also affect the relative concentrations of TTHM and HAA5 resulting in the formation of proportionally more TTHM or HAA5. Figure 2.2 illustrates this effect. In the example, TTHM is the predominant species formed at a water temperature of 24° C. However, the situation is reversed with greater HAA5 than TTHM concentrations when the water temperature reaches 3° C.

Figure 2.2 Impact of Water Temperature on DBP Speciation



Source: A. Franchi and C. Hill (2002).

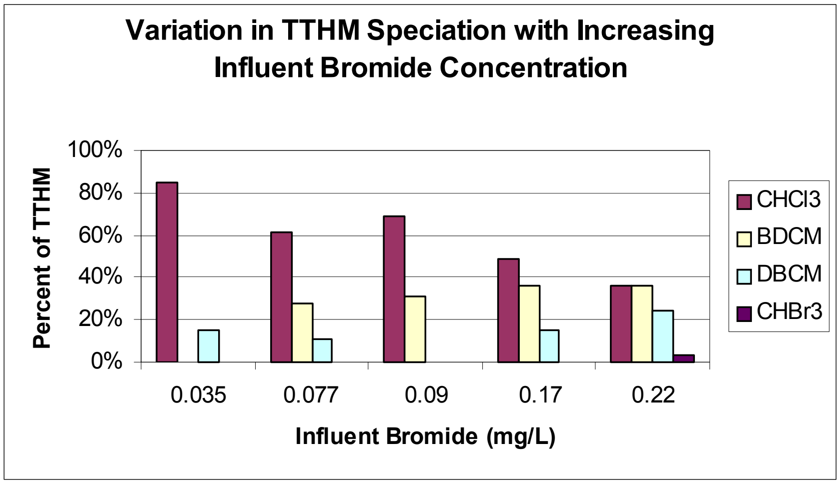
2.2.3 Increase in Source Water Bromide Concentration

Some source waters may experience periodic changes in bromide concentration. For example, as an aquifer's water level decreases, the bromide concentration of ground water from that aquifer may increase, resulting in higher than normal bromide levels during drought conditions. As the aquifer is recharged, bromide concentrations are diluted to normal levels. Brackish water or seawater intrusion into ground water and surface water sources due to withdrawals or drought conditions are other potential causes of increased bromide concentrations.

An increase in the source water bromide concentration can increase the formation of brominated THM and HAA species. This may be accompanied by corresponding decreases in chlorinated THM and HAA species. However, it can result in an overall increase in TTHM and HAA5 concentrations.

Figure 2.3 demonstrates the impact of bromide concentration on THM speciation. The figure shows individual THM species as a percent of TTHM. For this particular source water, at low bromide concentrations the TTHM concentration consists almost entirely of chloroform. As the bromide concentration increases, the concentration of the brominated THM species increases, and is accompanied by a decrease in the chlorinated THM species (both as a percent and as a measured concentration). Although not shown, similar trends can occur for HAA species.

Figure 2.3 Impact of Bromide Concentration on TTHM Speciation



Source: C. Hill (2002). [To be published.]

2.2.4 Change in NOM Characteristics

The characteristics of NOM in a system can have significant impacts on the formation of DBPs. NOM can be derived from many sources in a watershed, such as decomposition of vegetation and dead organisms. Water and wastewater treatment plant discharges, agricultural and urban area runoff, and septic system leachate discharge are other potential sources of NOM.

NOM is typically classified as either hydrophilic (more soluble) or hydrophobic (less soluble and containing a greater aromatic fraction). Hydrophilic NOM is more difficult to remove than hydrophobic NOM, but also forms fewer DBPs than hydrophobic NOM (Liang and Singer, 2001). Therefore, an increase in the concentration of hydrophobic NOM may be accompanied by an increase in DBP concentrations. Potential causes which may change the balance between hydrophilic and hydrophobic fractions of NOM include the following events:

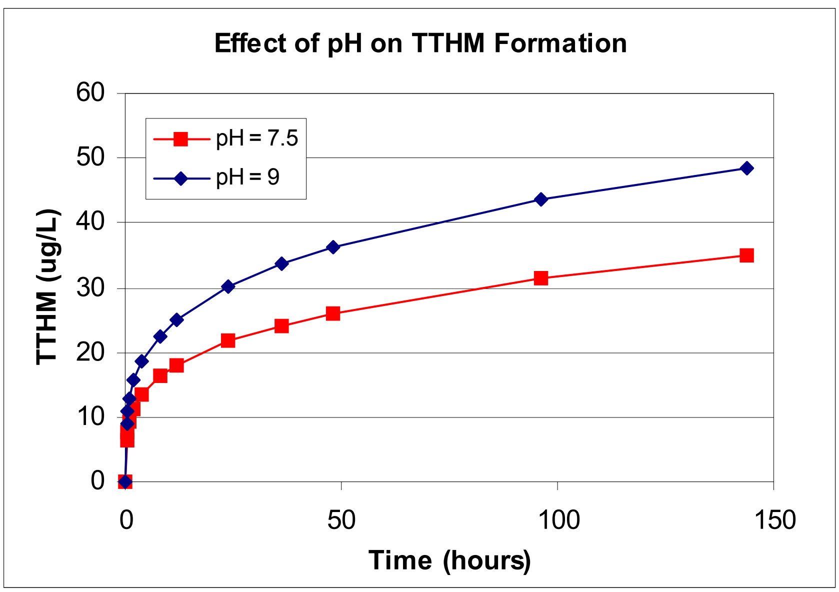
- Rain events that can wash organic matter of terrestrial origin (normally more hydrophilic) into a receiving water body.
- Algal blooms that result in the production of aquagenic organic matter (more hydrophobic).
- Surface water intrusion into ground water supplies which can affect the composition of NOM in the blended water.

2.2.5 Changes in Other Source Water Characteristics

Changes in other source water characteristics, such as pH or alkalinity, can impact TTHM and HAA5 formation. Increases in pH can affect DBP formation in several ways. Most coagulation processes using metal salts, such as alum and ferric chloride, are optimized at pH less than 7. Therefore, increases in source water pH may be detrimental to the coagulation process (assuming no pH control is available at the treatment plant), resulting in less NOM removal and leaving more NOM available for reaction with chlorine or other disinfectants downstream in the treatment process.

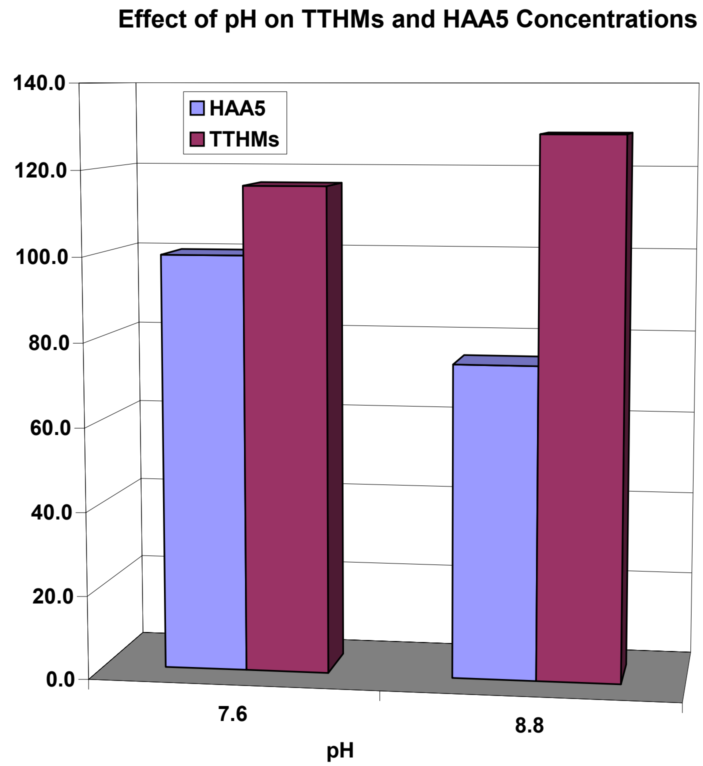
Increasing pH conditions typically lead to increasing TTHM and decreasing HAA5 concentrations. Figures 2.4 (for TTHM only) and 2.5 (for TTHM and HAA5) illustrates this effect. It is worth mentioning that many plants adjust pH to above 7 for corrosion control and, thus affect the balance between TTHM and HAA5 concentrations.

Figure 2.4 Effect of pH on TTHM Formation



Source: Plot obtained using the mathematical model developed by Amy et al. (1987).

Figure 2.5 Effect of pH on TTHM and HAA5 Formation
(results obtained through SDS tests, DBPs measured after a time correspondent to plant effluent, the chlorine residual after application was 2.3 mg/L)



Source: Data from Franchi et al., 2002

Increases in source water alkalinity can also result in an increase in TTHM and HAA5 concentrations. Alkalinity serves as a buffer and minimizes the reduction in pH which typically results from the addition of a coagulant during the treatment process. High alkalinity can reduce NOM removal during treatment as a result of the higher process pH.

2.2.6 Change in Raw Water Supply

Seasonal changes in source water supplies or the use of a temporary water supply may also result in an increase in TTHM and HAA5 concentrations. For example, a system that supplements a low-NOM ground water source with surface water supply during the summer may experience increases in DBPs as a result of increased source water NOM, or increases in source water temperature (surface water supplies are typically warmer than ground water supplies during summer months). On the other hand, a system that supplements its surface water supply with high-bromide ground water may also experience an increase in DBP concentrations.

2.3 Impacts of Changes in Treatment Plant Operations on DBP Concentrations

Changes or deficiencies in treatment practices can increase TTHM and HAA5 concentrations. This section describes the potential impact of common changes in treatment processes, including the following common treatment units:

- Pretreatment
- Coagulation/flocculation
- Settling
- Filtration
- Disinfection

Lastly, this section discusses the impact of treatment plant shutdowns on DBP formation.

2.3.1 Pretreatment

The primary causes of increased TTHM and HAA5 formation resulting from the pre-treatment process include:

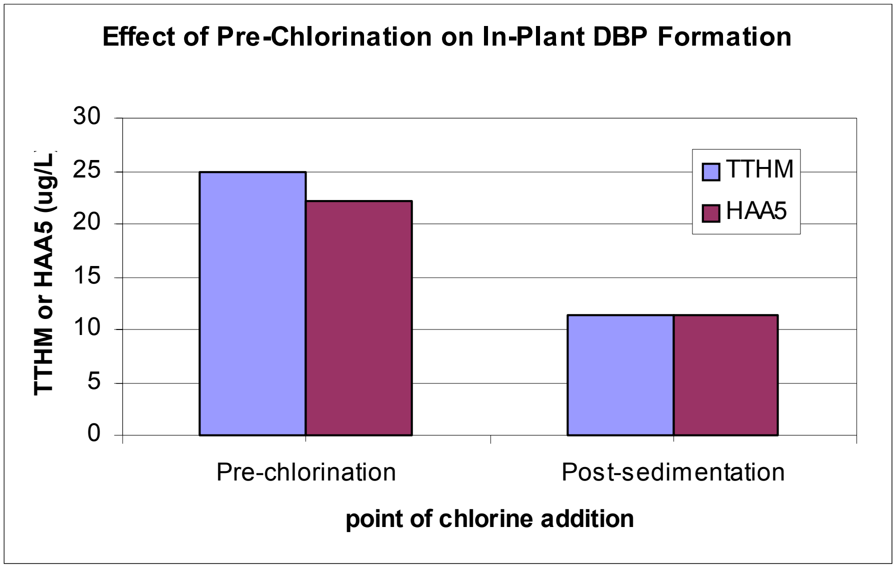
- Increases in raw water storage holding time
- Poorly controlled or excessive pre-chlorine dose
- Change in oxidant

As previously discussed, the rate of TTHM and HAA5 formation increases as temperature increases. Long detention times in raw water storage basins may cause source water temperature to increase and consequently, increase the amount of TTHM and HAA5 formed.

Pre-oxidation of raw water with chlorine is a common practice used for several reasons, including color removal, taste and odor control, iron and manganese removal, hydrogen sulfide control and removal, and coagulation enhancement. However, because of the large concentration of NOM and the long residence time available for the reaction with chlorine adding chlorine to the raw water can result in high DBP concentrations. Figure 2.6 illustrates that greater DBP concentrations are produced when chlorine is added to the raw water than when added to the settling basin effluent.

Figure 2.6 Effect of Pre-Chlorination on In-Plant DBP Formation

(results obtained through SDS tests, DBPs measured after a time correspondent to plant effluent, the chlorine residual after application was 1.5 mg/L)

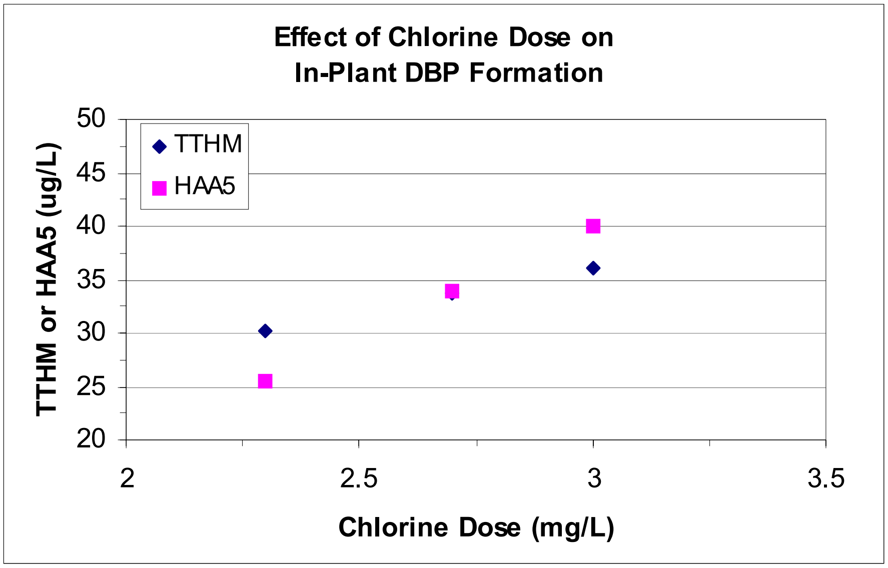


Source: A.
Franchi and C. Hill (2002).

An increase in the chlorine dosage can increase TTHM and HAA5 concentrations. High chlorine dosages may be intentionally applied during periods of algal bloom for the control of color, taste, and odor. There can also be unintentional results of poor chemical feed regulation amplified by a decrease in water volume processed by the plant or equipment failure. Changes in the plant process which involve the use of pre-oxidation with chlorine (i.e., for arsenic treatment) may also increase DBP formation. Figure 2.7 demonstrates the impact of the chlorine dose on in-plant DBP formation.

A change in the pre-oxidant type may result in an increase in DBP concentrations. Systems that change from using potassium permanganate as a pre-oxidant (which does not form TTHM and HAA5) to using chlorine for disinfection credit may experience increases in TTHM and HAA5 as a result. Similarly, systems that switch from chlorine to ozone will likely experience a decrease in plant TTHM and HAA5 concentrations. However, ozonation can result in increases in bromate concentrations (also a regulated DBP) in systems with sufficient bromide present in the source water.

Figure 2.7 Impact of Increasing Chlorine Dose on In-Plant DBP Formation
(results obtained through SDS simulations, DBPs measured after a time correspondent to plant effluent, the chlorine added after flash-mixing, residual after application was 1.5 mg/L)



Source: A. Franchi and C. Hill (2002).

2.3.2 Coagulation/Flocculation

The primary causes of increased TTHM and HAA5 formation during the coagulation/flocculation process include the following events:

- Changes in the raw water matrix that are not adequately addressed with process control.
- Spikes in the influent NOM concentration (e.g., when backwash water is returned to the plant influent) that are not addressed by treatment process adjustments (e.g., coagulant dose).
- Poor regulation of coagulant feed rate or coagulant equipment failure.
- Poor regulation of chemicals (including lime, caustic, or acid) used to control pH and/or chemical feed equipment failure.

The coagulant type (e.g., alum or ferric chloride) and dose are critical to the effective removal of NOM. An inadequate coagulant dose or poorly selected coagulant may result in a larger fraction of NOM passing through the coagulation/flocculation and settling processes. This increased NOM concentration can lead to increased formation of TTHM and HAA5.

Filter backwash may contain elevated concentrations of NOM. If no additional treatment (e.g., coagulation/settling) of recycled backwash water is provided, it is important to adjust the coagulant dose to account for the resulting increase in NOM. Similarly, if an increase in source water NOM is not accompanied by a corresponding increase in the coagulant dose, additional NOM will likely be present at the point of chlorination and will likely increase TTHM and HAA5 formation.

During coagulation, pH variations can affect NOM removal and DBP formation. Generally, NOM removal decreases as pH increases. If less NOM is removed during the coagulation process, then more NOM is available for TTHM and HAA5 formation in the downstream treatment process (see Figure 2.1). Since higher pHs favor THM formation reactions, increasing pH tends to increase TTHM levels in relation to HAA5 (see Figures 2.4 and 2.5).

2.3.3 Settling

If a chlorine residual is carried through the settling basin, TTHM and HAA5 levels can increase as a result of:

- Poor regulation of chlorine dose due to improper feed rate control or equipment failure

- Increased holding time for settling due to reductions in plant flow

Both of these circumstances, independently or in combination, can cause increases in TTHM and HAA5 concentrations. The effects of increasing chlorine dose on TTHM and HAA5 levels have been previously illustrated in Figure 2.7.

Process changes can still result in the occurrence of peak TTHM or HAA5 even if the chlorine residual is not carried through the settling basin(s). For example, poor or inadequate removal of sludge from the settling basin, as well as maintenance in the basin that stirs or moves the sludge, can release soluble or particulate NOM. This “additional” NOM load is available for reaction with chlorine in the basin, or may be carried through the settling process to the point of disinfection addition.

2.3.4 Filtration

Increases in organic loading during a filter cycle, or the breakthrough of particles at the end of the filter cycle run, result in an increase of DBPs entering the distribution system. When biologically active filters and granular activated carbon (GAC) filters are used for organic precursors removal, breakthroughs may be a concern because soluble organic compounds can be released. Likewise, when GAC columns are used for DBP removal after chlorination, exhaustion of adsorptive capacity may result in sudden TTHM and HAA5 peak concentrations in the finished water.

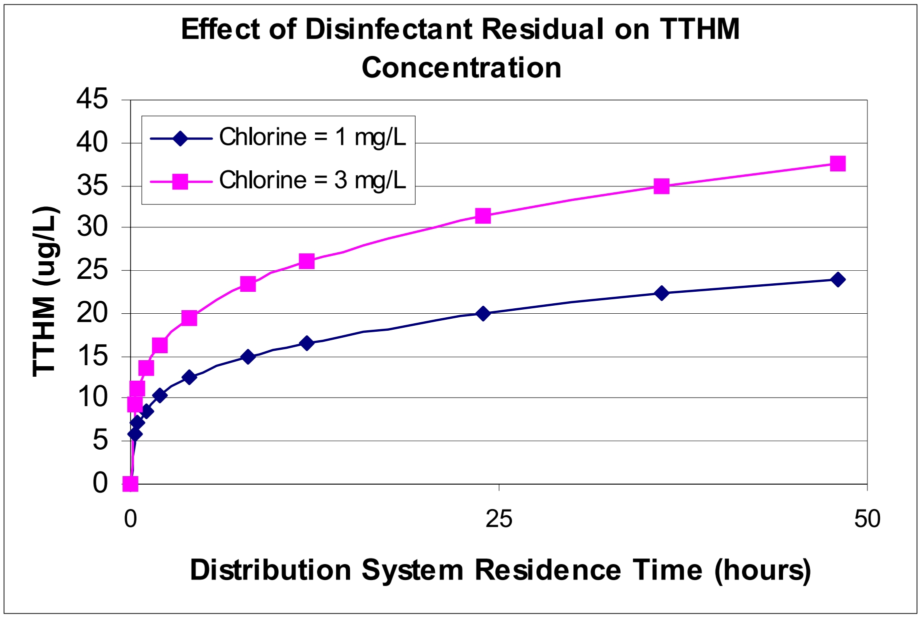
2.3.5 Disinfection

The following disinfection related events can increase the formation of TTHM and HAA5:

- Increased chlorine dose and/or residual (intentional or unintentional)
- Increased holding time of water in the clearwell
- Changing point of chlorine addition
- Changes in primary disinfectant type
- Free chlorine "burnout" periods in chloraminated systems

Systems are required by the Surface Water Treatment Rule (SWTR), Interim Enhanced Surface Water Treatment Rule (IESWTR) and Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) to maintain a certain level of CT (disinfectant residual × contact time) for disinfection. As the disinfectant dose decreases, the required contact time increases to maintain a required level of CT, and vice versa. An increase in the disinfectant dose (particularly chlorine) can increase TTHM and HAA5 concentrations. The change in disinfectant dose may be intentional or unintentional. For example, systems that control the disinfectant dose manually and not based on plant flow may experience increases in TTHM and HAA5 if the plant flow rate suddenly decreases or the dose is not adjusted frequently to account for reductions in plant flow. In such instances, those systems would likely be overdosing chlorine. On the other hand, a system may intentionally increase the dose to account for a decrease in water temperature and maintain the required CT (CT requirements increase as water temperature decreases). Figure 2.8 shows the impact of residence time on TTHM concentrations at two disinfectant residual concentrations. The effect of residence time on HAA5 concentrations is similar, but less pronounced. In other words, HAA5 formation occurs more rapidly and may not increase as significantly as TTHM over long periods of time (particularly in chloraminated systems).

Figure 2.8 Effect of Disinfectant Residual and Residence Time on TTHM



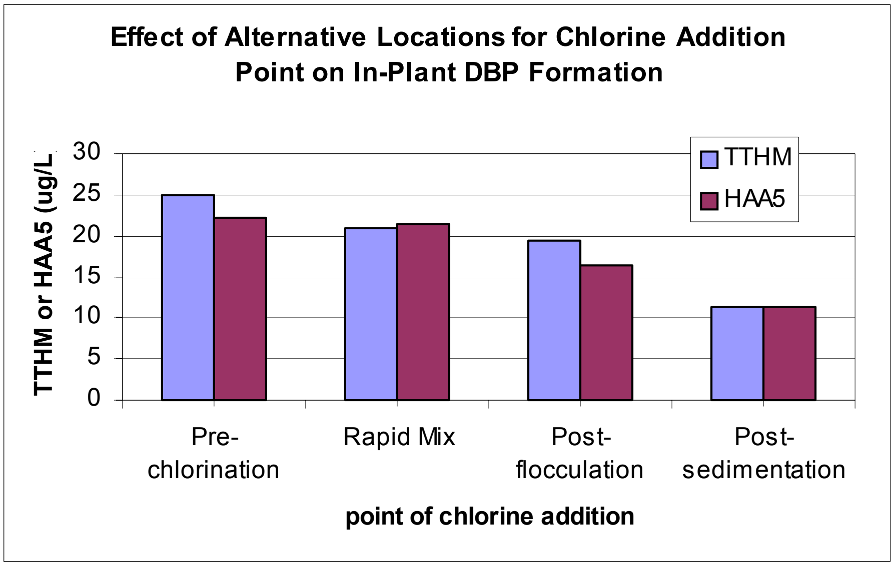
Source: Plot obtained using the mathematical model developed by Amy et al. (1987).

Poor mixing in the clearwell can result in dead zones where the hydraulic residence time is significantly higher than the residence time of the bulk of the water passing through the clearwell. As a result of the increased contact (i.e., reaction) time, TTHM and HAA5 concentrations may be significantly higher in the dead zones. Section 2.4 discusses this issue in greater detail. A reduction in system demand (particularly in a system with little or no storage beyond the clearwell) may also result in longer hydraulic residence times in the clearwell and increased TTHM and/or HAA5 concentrations.

In addition to changes in detention time and dose in the clearwell, changing the point of chlorine (or other disinfectant) addition can have a significant impact on TTHM and HAA5 formation. Systems that practice pre-chlorination (i.e., addition of chlorine to raw water) will likely form more TTHM and HAA5 as a result of the higher NOM content of the water prior to coagulation and clarification, as well as the increased contact time through the treatment plant. Similar effects are likely for systems that add chlorine to the rapid mix basin, as NOM typically has not yet been removed from the raw water at this point in the treatment plant. Systems that add chlorine following clarification, or post-filtration, will likely experience lower TTHM and HAA5 concentrations because of the removal of NOM prior to chlorine addition.

Figure 2.9 shows the effect of the point of chlorination on treatment plant TTHM and HAA5 concentrations. As shown in the figure, there is little difference in TTHM and HAA5 between pre-chlorination and rapid mix. This is primarily due to the fact that no NOM has been removed from the water at this point in the treatment process. However, when the point of chlorine addition is moved to post-sedimentation, in-plant TTHM and HAA5 concentrations are reduced by greater than 70% and 50%, respectively.

Figure 2.9 Effect of Point of Chlorination on TTHM and HAA5 Concentrations



Source: A. Franchi and C. Hill (2002).

Systems that change the point of chlorine addition seasonally to adjust for changes in raw water quality may experience fluctuations in DBPs as a result of those changes. For example systems where pre-chlorination is used seasonally to control taste and odor may see increases in TTHM and HAA5 concentrations during those periods.

Many systems have converted to chloramines for secondary disinfection to reduce TTHM and HAA5 formation. Use of chloramines can lead to nitrification in the distribution system, causing microbiological and taste and odor problems. Some chloraminated systems periodically switch to free chlorine for a "burnout" period to inactivate the nitrifying bacteria. During these burnout periods, systems may experience temporary increases in TTHM and HAA5 concentrations.

2.3.6 Plant Shutdowns

Plant shutdowns and routine start/stop operations can lead to peak TTHM and HAA5 concentrations. During shutdowns, the holding time of chlorinated water within the plant can be long and result in the formation of higher than normal TTHM and HAA5 concentrations. When the plant is placed back in service, water containing high TTHM and HAA5 levels may enter the distribution system. Similar increases in TTHM and HAA5 concentrations may be observed at the beginning of each working cycle at plants that operate less than 24 hours per day. Effect of filter spikes coagulation not optimized in start/stop operations. Even small start spikes can increase NOM. In these plants, the residence time can be extremely long. If a plant practices pre-chlorination, significant concentrations of TTHM and HAA5 may form in the treatment plant.

2.4 Impacts of Distribution System Characteristics on DBP Concentration

This section discusses distribution system conditions which may result in higher than normal formation of TTHM and HAA5. Specifically, this section discusses:

- Poor mixing and inadequate volume turnover in storage tanks
- Dead ends and stagnant zones in the distribution system
- Use of booster disinfection
- System maintenance activities

2.4.1 Poor Mixing and Inadequate Volume Turnover in Storage Tanks

To illustrate water quality problems associated with storage tanks, Table 2.1 presents free chlorine, TTHM, and HAA5 concentrations at the top and bottom of three tanks. Each tank has a common inlet/outlet located at the bottom of the tank. Each tank is also poorly mixed, as evidenced by the difference in free chlorine concentrations at the top and bottom of the tank, but each has a different associated water quality problem.

Table 2.1 Free Chlorine, TTHM, and HAA5 Data for Five Storage Tanks

Tank No.	Free Cl_2 @ Top of Tank	Free Cl_2 @ Bottom of Tank	TTHM @ Top of Tank	TTHM @ Bottom of Tank	HAA5 @ Top of Tank	HAA5 @ Bottom of Tank
1	0.3	1.3	110	72	57	61
2	0.2	1.0	130	59	12	44
3	0.0	1.0	98	99	31	61

Source: Mahmood (2002). [To be published.]

<u>Tank 1</u> Free chlorine concentration is relatively low at the top of the tank. TTHM concentration is higher in the top of the tank. HAA5 concentration is fairly consistent indicating HAA5 formation has stopped, or more likely the early stages of biodegradation of HAA5.

Tank 2 Like Tank 1, TTHM concentration has increased in the top of the tank, but biodegradation of HAA5 has clearly begun.

Tank 3 Based on TTHM data, it would appear the tank is well mixed. However, the difference in free chlorine and HAA5 concentrations indicate otherwise. This demonstrates the importance of looking at multiple parameters when evaluating mixing in storage tanks.

Under normal daily operation, older water or unmixed portions of the stored water at the top of these tanks may not be utilized. However, events such as a main break or fire flow can draw water from the portions of the tank with high water age (and high TTHM and/or HAA5 concentrations) into the distribution system.

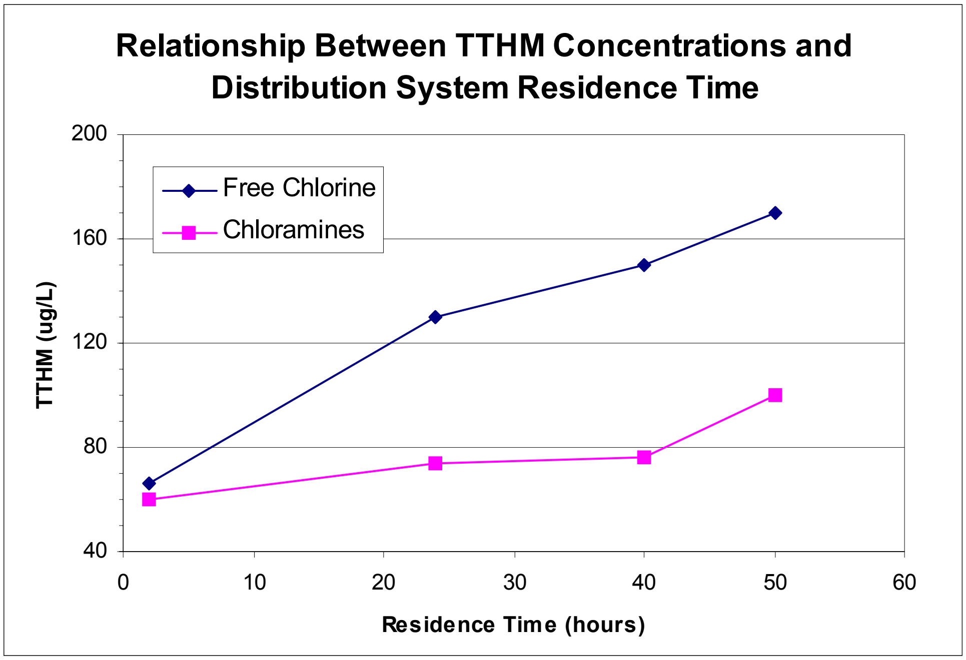
2.4.2 Dead Ends and Stagnant Zones in the Distribution System

Dead ends in a distribution system can lead to excessive water age. A dead end may be the result of distribution piping configuration (e.g., the actual end of a long pipe with few connections) or valving configuration (e.g., a closed valve that prevents flow from one area to another).

The water age in a stagnant zone can also be very high. Stagnant zones are created when water flow from opposing directions meets at a location where there is little or no water demand. There is no net water movement in any direction in that particular location and, therefore, fresh water cannot flow to a stagnant zone from other areas. When there is an unusual shift in water demand pattern in the vicinity of a stagnant zone, high age water from the stagnant areas can flow to other parts of the distribution system and become available for consumption. The shift in water demand pattern can be due to several factors including: unusually high water demand (e.g. large customers on/off line); increased seasonal demand; changes in the water pressure, or flow patterns and flow rates (e.g., when a seasonal groundwater source is directly fed into the distribution system).

Figure 2.10 shows the effect of distribution system residence time on TTHM concentrations for both free chlorine and chloraminated systems. Note that the effect of water age is more dramatic for chlorine systems than for chloramine systems (see Appendix A for a discussion of formation kinetics).

Figure 2.10 Relationship Between TTHM and Distribution System Residence Time



Source: A. Franchi and C. Hill (2002).

2.4.3 Booster Disinfection

Booster disinfection is often used to maintain a disinfectant residual in sections of a distribution system that might not otherwise maintain a residual. In some cases, booster disinfection is used on an intermittent basis based on water quality conditions. For example, the loss of chlorine residual in certain sections of a distribution system may be due to a seasonal change in the source water, changes in the water demand, or may occur during the summer when higher temperatures promote microbial growth and increase chlorine demand, warranting use of booster chlorination.

When properly controlled and coordinated with the treatment plant disinfection process, booster disinfection can be used to reduce average distribution system DBP concentrations. To accomplish this, the disinfectant dose applied at the plant must be minimized to reduce DBP formation while maintaing the necessary residual in the distribution system prior to the boosting station. The booster disinfectant dose is then added to maintain a residual to the end of the system.

While booster disinfection can reduce system average DBP concentrations, DBPs are likely to increase after booster disinfection is applied. Table 2.2 illustrates this point, showing DBP concentrations for locations before and after booster disinfection. Prior to booster disinfection (water age = 24 to 40 hours), the TTHM concentration remained fairly constant because the disinfectant residual was nearly depleted. On the other hand, as the disinfectant residual depleted (suggesting microbiological activity), the HAA5 concentration decreased substantially. After booster chlorination, both TTHM and HAA5 concentrations increased (HAA5 increased beyond the concentrations present before biodegradation).

Table 2.2 Effect of Booster Chlorination on TTHM and HAA5 Concentrations
(Concentrations measured at various locations in the distribution system)

	Before Booster Chlorine Addition			**After Booster Chlorine Addition**		
Water Age (Hours)	2	24	40	41	50	70
TTHMs (ppb)	66	130	150	160	170	170
HAA5 (ppb)	41	47	7	77	95	71
Free Chlorine Residual (mg/L)	2.6	0.3	0.0	1.0	2.2	0.5

Source: A. Franchi and C. Hill (2002)

The location of the booster station can also impact the effectiveness of booster disinfection at reducing system average DBP levels. The use of several smaller booster stations closer to the end of the system may be more effective in reducing system average DBP levels compared to a single large station that treats a much larger percentage of the system water, some of which may not need additional disinfection. Several smaller booster stations can also allow the total amount of added disinfectant to be reduced compared to a single large booster station.

2.4.4 System Maintenance Activities

Disinfection of new or repaired distribution system piping is typically accomplished using a highly concentrated (> 25 ppm) chlorine solution. Failure to properly flush a section of new or repaired pipe before placing it into service can introduce excessive amounts of chlorine to the distribution system and result in short-term spikes in TTHM and HAA5 concentrations. AWWA Standard C651-99, *Disinfecting Water Mains*, provides more detailed information regarding the disinfection of new and repaired distribution system piping.

Frequently, pipe repair work is accompanied by the closure of valves to isolate sections of pipes. This changes the flow patterns in surrounding areas of the distribution system, which can potentially cause stagnant water with high DBP levels to flow into areas of the distribution system serving customers. Also, after repair work is completed, the repair crew may fail to open all the valves that were closed due to construction work which can create artificial dead ends.

3.0 Identifying the Cause Of and Documenting a DBP Significant Peak Excursion

Under the Stage 2 DBPR, if a significant excursion occurs, systems are required to evaluate distribution system operations to identify opportunities to reduce DBP levels and discuss the evaluation with the State no later than the next sanitary survey (40 CFR 141.626). This chapter provides guidelines to help identify the cause of an excursion event and presents a template for documenting the evaluation of it (referred to as a "Significant Excursion Evaluation Report"). Distribution system best management practices that can be implemented to reduce peak DBP concentrations are discussed in Chapter 4.

The Significant Excursion Evaluation Report form begins on page 3-3. A supplemental form for recording water quality data is presented on page 3-13. While the use of these forms is not required, a significant excursion evaluation report should be detailed enough to provide information regarding the location and cause of the excursion, as well as any proposed changes or actions intended to prevent the reoccurrence. At a minimum, the documentation should include:

1. Location, date, and time that the excursion sample(s) was collected. (Were multiple excursions recorded during this sampling period? If so, and it is believed the excursions are related, only one report is needed.)

2. Schematic or map showing the location of each excursion relative to the distribution system and treatment plant(s).

3. Summary of monitoring results from this sampling period.

4. Historical summary of DBP concentrations at the excursion sample location(s). (Has this sample location had a significant excursion before? If yes, when did the previous excursion(s) occur?)

5. Perceived cause of the significant excursion. The template in this chapter includes a checklist to help identify the cause(s) of the peak.

6. Steps taken or planned to reduce future peaks.

Examples of peak excursion evaluation reports and completed checklists are provided in the appendices:

Appendix	Cause of Significant Peak Excursion
B	Changes in source water quality
C	Changes in treatment plant operation
D	Changes in distribution system operation
E	Changes in treatment plant and distribution system operation

Significant Excursion Evaluation Report

Page 1

Report date: ______________________________

Report prepared by: ________________________

System name: ______________________________

1) When was the significant excursion sample(s) collected? What were the TTHM and HAA5 concentrations?

Location No.	# ______	# ______	# ______	# ______
Location description				
Sample collection date				
Sample collection time				
TTHM LRAA Concentration (ug/L)				
TTHM Concentration (ug/L)				
HAA5 LRAA Concentration (ug/L)				
HAA5 Concentration (ug/L)				

Note: Attach additional sheets if you observed more than four significant excursions during this round of sampling.

2) Where did the excursion(s) occur? Attach a schematic of your system, sketch your system in the space below, or have a schematic of your system available to review with your state at the time of your next sanitary survey. Indicate the location(s) of the significant excursion(s) on your schematic.

Report date: ________________

3) Attach (or provide in the Supplemental Data Form) all available water quality data for the round of sampling in which the significant excursion occurred. At a minimum, include all TTHM and HAA5 results from the sampling period. You should also consider including pH, temperature, alkalinity, TOC, disinfectant residual, and any other data that you think would be useful.

   a) Were there any unusual circumstances associated with this round of sampling?

      Yes____ No____

      If yes, please explain.

   b) Were all analytical QA/QC measures met?

      Sample preservation Yes____ No_____

      Sample holding time Yes____ No_____

      Other ____________________

      ____

      ____

      If no, please explain.

4) Attach (or provide in the Supplemental Data Form) historical TTHM and HAA5 data for the location(s) at which the significant excursion(s) occurred. Provide at least three years of data, if available.

Significant Excursion Evaluation Report

Page 3

Report date: ________________

5) What caused your excursion(s) to occur?

Sections A through F starting on page 4 can help you determine the possible cause(s) of your excursion. <u>Please note there may be more than one factor which resulted in your excursion</u>.

Section A: Source water quality change
Section B: Process upset at treatment plant
Section C: Planned change or maintenance activities at plant
Section D: Planned distribution system operations or maintenance activities
Section E: Unplanned events in distribution system

If you already suspect a cause, go directly to that section. If you read Sections A through E and are unable to determine a cause of your excursion, then complete Section F.

Consecutive systems should also contact their wholesaler to identify the cause(s) of the significant excursion(s).

6) List steps taken or planned to reduce DBP peak levels.

Significant Excursion Evaluation Report
Page 4

Report date: ________________

A. Source Water Quality Changes

- Did any of the events listed below take place before the DBP excursion to cause TOC levels to increase?
  - Heavy rain fall
  - Flooding
  - Spring snow-melt/runoff
  - Significant decrease in rainfall or source flow
  - Algae bloom
  - Reservoir turnover

- Did any of the events listed below take place before the DBP excursion to cause bromide levels to increase?
  - Significant decrease in rainfall or source flow
  - Brackish or seawater intrusion

- Did pH and/or alkalinity significantly change?

- If two or more supplies are used, was a greater portion of water drawn from the one with higher TOC?

- Was raw water stored for an <u>unusually long</u> period of time resulting in a <u>significant increase</u> in water temperature?

Conclusions:

Did source water quality changes cause or contribute to your significant excursion(s)?

Yes ____ No ______

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Report date: ________________

B. Process Upset at Treatment Plant

- Was raw water stored for an unusually long time, providing additional contact time for DBP formation after prechlorination?

- Were there changes in coagulation practices?
  - Were there any changes or malfunctions of the coagulation process in the days leading to the excursion?
  - Were the coagulant dose and pH properly adjusted for incoming source water conditions?
  - Were there any feed pump failures, or were feed pumps operating at improper feed rate?

- Were there changes in chlorination practices?
  - Were there any changes in chlorine dose at any location in the plant?
  - Were there changes in plant flow that may have resulted in longer than normal residence time at any location in the plant?
  - Did the pH change at the point of chlorine addition?
  - Were there any feed pump failures, or were feed pumps operating at improper feed rate?

- Were there changes in settling practices?
  - Was there excess sludge build-up in the settling basin that may have carried over to the point of disinfectant addition?
  - Was there any disruption in the sludge blanket that may have resulted in carryover to the point of disinfection?
  - Were there large changes in plant flow rate that may have resulted in a decrease in settling time or carry over of process solids?

- Were there changes in filtration practices?
  - Have filter run times been changed to meet raw water quality changes?
  - Were there any spikes in individual filter effluent turbidity (which may indicate particulate or colloidal TOC breakthrough) in the days leading to the excursion?
  - Did chlorinated water sit in the filter for an extended period of time?
  - Were all filters run in a filter-to-waste mode during initial filter ripening?
  - Were any filters operated beyond their normal filter run time?
  - If GAC filters are used: Is it possible the adsorptive capacity of the GAC bed was reached before reactivation occurred?
  - If biological filtration is used: Were there any process upsets that may have resulted in breakthrough of TOC (particularly biodegradable TOC)?
  - Were there significant increases in filter loading rates?

- Were there changes in plant flow (i.e a temporary plant shutdown) that may have resulted in an unusually high residence time in the clearwell on the days prior to the excursion?
  - For example, a temporary plant shutdown.

- Were there any other equipment failures or process upsets?

Continued on next page

Report date: ________________

B. Process Upset at Treatment Plant (Continued)

Conclusions:

Did a process upset in the treatment plant cause or contribute to your significant excursion(s)?

Yes____ No _____

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Significant Excursion Evaluation Report

Page 7

Report date: ________________

C. Planned Change or Maintenance Activities for the Treatment Plant

- Was there a recent change (or addition) of pre-oxidant?
- Was there any maintenance in the basin that may have stirred sludge from the bottom of the basin and caused it to carry over to the point of disinfectant addition?
- Did you change the type or manufacturer of the coagulant?
- Were there any changes in disinfection practices in the days prior to the excursion?
  - For example, a switch from chloramines to free chlorine for burnout period.
  - Discontinuation of ozone.
  - Prechlorination affecting biological filtration
- Was a filter(s) taken off-line for an extended period of time that caused the other filters to operate near maximum design capacity and creating the conditions for possible breakthrough?
- Were any pumps shut down for maintenance, leading to changes in flow patterns or hydraulic surges?

Conclusions:

Did a planned maintenance or operational activity in the treatment plant cause or contribute to your significant excursion(s)?

Yes_____ No _____

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Report date: ________________

D. Planned Distribution System Operations or Maintenance Activities

- Was a tank drained for cleaning or other maintenance?
  - Was the tank drained to waste or to the distribution system?
  - Was the tank returned to service directly to the system after disinfection with a high residual remaining
  - Was a larger volume than normal drained to the distribution system?

- If booster disinfection is used, was the booster disinfectant dose higher than the normal booster disinfectant dose for that season?

- Were there any system maintenance activities in the days prior to DBP excursion? Including:
  - Repairing mains or installing new mains
  - Closure of valves to isolate sections of pipes

- Were the pipes flushed properly or were the appropriate valves re-opened after work was completed?

- Did any pump or pipeline maintenance occur that would have changed the flow pattern in the area the sample was drawn from?
  - Change in flow can cause water in stagnant areas to be drawn into another area.

- Did any pipeline replacement occur?
  - Disinfecting piping could result in a high concentration of chlorine entering the distribution system and thus increase DBPs.

Conclusions:

Did a planned distribution system maintenance or operational activity cause or contribute to your significant excursion(s)?

Yes_____ No _____

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

E. Unplanned Distribution System Events

- Were there increases in demand that caused older water in storage tanks to be drawn into the system?
  - Were there any major fire events?
  - Did one or more storage tank have greater than average drawdown preceding the time of DBP peak excursion?

- Were there decreases in demand that resulted in longer than normal system residence times?
  - Were there any large customers off-line?

- Did any main breaks occur causing changes in flow patterns in the influence area of the sample location?

- If you collect water temperature inside storage tanks, was the temperature inside the tank higher than normal for the season?

- Were any storage tanks hydraulically or mechanically isolated from the system for an extended period and then used preceding the time of DBP peak excursion?

- Did changes in overall water demand cause a change in water demand patterns in the vicinity of dead ends and/or stagnant zones in the system?

- Were there large variations in localized system pressures that were different from the normal pressure range that could have caused a change in water demand patterns in the vicinity of dead ends and/or stagnant zones in the system?

Conclusions:

Did an unplanned distribution system maintenance or operational activity cause or contribute to your significant excursion(s)?

Yes____ No _____

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Report date: ________________

F. If you were unable to identify the cause of your significant excursion(s) after reviewing Sections A through E, are you able to identify another potential cause of your increase in DBP concentrations? Explain.

Note: *If you are unable to determine the cause of your excursion you may wish to consider:*

- More frequent raw water temperature monitoring.
- More frequent raw water TOC monitoring.
- Increased disinfectant residual monitoring in the distribution system.
- Tracer studies to characterize distribution system water age.
- Development of a hydraulic model to characterize the distribution system.

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Supplemental Data Form for the Significant Excursion Evaluation Report	Report date: ____________ Report prepared by: ____________ System name: ____________

1) Water quality data from significant excursion sampling period.

Location No.	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**
Location Name								
TTHM (ug/L)								
HAA5 (ug/L)								
Free Chlorine (mg/L)								
Total Chlorine (mg/L)								
pH								

2) Supplemental data from each treatment facility:

Plant #1:
Raw Water Temperature: ____________

Plant Effluent Water Temperature: ____________

Raw Water TOC: ____________

Other Data: ____________

____

____

Plant #2:
Raw Water Temperature: ____________

Plant Effluent Water Temperature: ____________

Raw Water TOC: ____________

Other Data: ____________

____

____

3) Historical TTHM and HAA5 data at significant excursion sampling locations.

TTHM Data (ug/L)

Monitoring Location # _____ # _____ # _____ # _____
Date 1 ____________
Date 2 ____________
Date 3 ____________
Date 4 ____________
Date 5 ____________
Avg. ____________

HAA5 Data (ug/L)

Monitoring Location # _____ # _____ # _____ # _____
Date 1 ____________
Date 2 ____________
Date 3 ____________
Date 4 ____________
Date 5 ____________
Avg. ____________

Attach additional sheets if necessary

4.0 Best Management Practices and Distribution System Improvements to Reduce DBP Concentrations

It is common to find higher TTHM and HAA5 concentrations in the distribution system compared to concentrations leaving the treatment plant. In systems using free chlorine for secondary disinfection, significant increases in TTHM and HAA5 may occur in the distribution system. Water age, type and concentration of NOM, the disinfectant type, and residual concentration in the finished water are all factors that can affect TTHM and HAA5 concentrations. The previous chapter provided guidelines for identifying and documenting the cause of significant excursions. This chapter describes several options that can be used to reduce peak DBP concentrations in the distribution system, and is divided into the following sections:

- 4.1 Modifications to Improve Water Quality in Storage Tanks
  - 4.1.1 Minimizing Hydraulic Residence Time of Storage Tanks
  - 4.1.2 Improving Mixing Characteristics of Storage Tanks
- 4.2 Decommissioning Storage Tanks
- 4.3 Modifications to Improve Water Quality in Pipes
  - 4.3.1 Minimizing Hydraulic Residence Time in Pipes
  - 4.3.2 Reducing Disinfectant Demand
- 4.4 Booster Disinfection
- 4.5 Overall Strategy to Manage Water Age

4.1 Modifications to Improve Water Quality in Storage Tanks

As discussed in Section 2.4, storage tanks that are underutilized and have poor mixing characteristics can have water with a high residence time in certain portions of the tank, causing high DBP formation. Further, high temperatures in tanks during the summer season can increase DBP formation. Storage tanks should be designed and operated so the overall hydraulic residence time is minimized and the water is well mixed. Generally, water mixing in the finished water storage tanks is not achieved through mechanical mixers, but through the kinetic energy of the tank inflow. Low average hydraulic residence time and adequate mixing are critical factors for minimizing DBP formation in storage tanks.

Quiescent conditions in storage tanks may lead to sediment accumulation. This accumulation may result in loss of disinfectant residual and increased DBP formation. Operating procedures (control of empty/fill periods), inspections and maintenance activities can minimize this problem.

4.1.1 Minimizing Hydraulic Residence Time of Storage Tanks

Excessive hydraulic residence time in a storage tank can result in older water with high DBP levels. The average hydraulic residence time can be estimated by the following equation:

Average hydraulic residence time = $[V_{max}/(V_{max} - V_{min})]/N$

where, V_{min} = average minimum daily volume
V_{max} = maximum daily volume
N = number of drain/fill cycles per day

Example 4.1 shows how this formula can be used to calculate residence time in a real tank. The formula assumes that a tank is ideally mixed. In tanks with poor mixing characteristics, the residence time of portions of the water can be much higher than the average. The average hydraulic residence time in a storage tank can be reduced when the volume turnover is increased by extending drain cycles and/or increasing the number of drain/fill cycles per day. Pumps may need to be added to a storage tank to pump out water from the tank into the distribution system and thus increase the volume turnover of the tank. Changes in pumping cycles may be needed to increase volume turnover.

Example 4.1 Calculating the Average Hydraulic Residence Time

Assume Your City has a 3-MG storage tank located in the distribution system. The maximum volume (V_{max}) in the tank is 2 MG at any given time during a day. The minimum volume (V_{min}) in the tank is 1 MG at any given time during the day. There are four drain/fill cycles (N) per day. Calculate the average hydraulic residence time of the tank.

Average hydraulic residence time = [2/(2 - 1)]/4
= 0.5 days

4.1.2 Improving Mixing Characteristics of Storage Tanks

The following factors effect the mixing characteristics of storage tanks:

- Fill time
- Inlet momentum
- Inlet/outlet pipe location, orientation, and tank dimensions

Desktop theoretical evaluations of hydraulic residence time, fill time, and inlet momentum can be used to predict water mixing characteristics of a storage tank. In addition, temperature measurements inside a storage tank can be an effective tool in predicting the water mixing characteristics of the tank. A temperature profile can be developed by continually measuring the water temperature at various depths in the tank over the course of several days. The temperature profile can then be compared against tank water level data to determine the effectiveness of mixing and the existence of thermal stratification in the tank.

While the desktop theoretical evaluations and temperature measurements can describe mixing characteristics quantitatively, computational fluid dynamic (CFD) modeling can describe mixing characteristics qualitatively by providing visual images of water mixing inside a tank. The impact of design changes on mixing characteristics can be effectively visualized using CFD modeling, making this modeling a very useful tool to supplement desktop theoretical evaluations and temperature measurements.

The mixing predictions can be used to identify a storage tank with inadequate mixing characteristics and, therefore, a potential for high DBP formation. Based on the evaluations of mixing characteristics, physical and operational modifications can then be recommended to improve storage tank mixing.

4.1.2.1 Increasing Fill Time

For a tank operating in a fill and drain mode, mixing occurs primarily during the fill cycle. As a result, if a tank is relatively well-mixed at the end of each fill cycle, then significant variations in water age and DBP levels within the tank are unlikely. Experimentation has shown that the time required for good mixing is dependent upon the volume of water in the tank, the inlet diameter, and the filling flow rate. For some types of tanks, researchers have developed empirical relationships for the mixing time theoretically required to completely mix the water in the tank (Grayman et al., 2000). It is generally desirable for the actual filling time to exceed this theoretical mixing time. Therefore, one way of increasing fill time is to allow the tank to drain to a lower level before refilling.

4.1.2.2 Increasing Inlet Momentum

Inlet momentum (defined as velocity × flow rate) is a key factor for mixing of water in storage tanks. The higher the inlet momentum, the better the mixing characteristics in the storage tanks. Increasing the flow rate could be a simple way to increase momentum, but may not be practical due to limitations of system hydraulics. For example, a pump may not be available at the tank location and the distribution system pressure may not be high enough to get desirable increases in flow rates. In some cases, even if a pump were available, it may not be possible to increase the pumping rate into the tanks. In such cases, it may be more feasible to increase the inlet momentum by increasing the velocity with a reduced inlet diameter.

4.1.2.3 Optimizing Inlet Location and Orientation

Mixing a fluid requires a source of energy input. In distribution system storage tanks, this energy is normally introduced during tank filling. As water enters a tank, a jet is formed and the water present in the tank is drawn into the jet. Circulation patterns are formed that result in mixing. The path of the jet must be long enough to allow the mixing process to develop for efficient mixing to occur. Therefore, the inlet jet should not be pointed directly towards nearby impediments such as a wall, the bottom of the tank, or deflectors. The degree and speed of mixing depends primarily upon the size of the tank and the momentum of the incoming jet.

The location and orientation of the inlet pipe relative to the tank walls can have a significant impact on mixing characteristics. For example, when the height of a tank is much larger than the diameter or width, the location of the inlet pipe at the bottom of the tank in the horizontal direction is likely to cause the water jet to hit the vertical wall of the tank resulting in loss of inlet momentum and incomplete water mixing. Besides geometrical characteristics of tanks, the mixing of water is also depend on the initial water depth in the tank. When water level is high and the inlet pipe is oriented horizontally, the inlet momentum may not be sufficient to completely mix water during the fill cycle. Under both situations, high concentrations of DBPs may form in the older water stagnating at the top of the tank.

4.1.2.4 Avoiding Baffles

Water can be forced to flow through a storage tank either in a completely mixed state or a plug flow manner. In treatment plant contact chambers where there is generally simultaneous inflow and outflow, internal baffles are sometimes placed in tanks to encourage plug flow and avoid short-circuiting and dead zones. However, in distribution system tanks and reservoirs that are generally "fill and draw" operations, and where a mixed condition is preferable to plug flow, baffles can inhibit mixing and produce zones of poor mixing. These zones have higher water age and therefore higher DBP formation potential. Therefore, baffles should not be used in distribution system storage facilities under most circumstances.

4.1.2.5 Avoiding Tank Stratification

The temperature difference through the depth of a storage tank is referred to as thermal stratification. Thermal stratification can be either the result or the cause of poor mixing. Depending on the location of the inlet pipe and tank geometry, the water entering the tank from buried pipes may be cooler than the bulk water in the tank during the summer or warmer than the bulk water in the tank during the winter. In tanks with poor mixing characteristics (i.e., insufficient volume turnover or inlet momentum), colder, denser water may hover in the lower depths of the tank, whereas the warmer, less dense water will have a tendency to rise to the top of the tank. Temperature differences of less than 1°C can affect mixing characteristics.

Generally, tall tanks and tanks with large diameter inlets located near the bottom of the tank have a greater potential for thermal stratification. If significant temperature differences are experienced, then the orientation and diameter of the inlet pipes may need to be modified to reduce the potential for stratification.

4.2 Decommissioning Storage Tanks

A tank may be oversized for the water system needs and, thus, it may not be possible to get adequate flow and water turnover in the tank. A storage tank may also be hydraulically locked out of the distribution system due to high system pressures and low system demand, resulting in excessive water age and high DBP formation potential. When events such as main breaks or fire flow cause the water from these tanks to be drawn into the distribution system, the areas receiving water from the tank may have higher than normal DBP levels. For a tank that is hydraulically locked out under normal system operating conditions, physical modifications are ineffective to significantly improve mixing characteristics. In such cases, operational changes (such as reducing normal operating tank water level or increasing draw cycle time duration) or permanent decommissioning can be considered to prevent water with high DBP levels from entering the distribution system.

Before a tank is decommissioned, the effects of taking the tank out of service should be determined. A distribution system analysis should be performed to make sure that the tank is not needed for equalization storage, fire flow, or emergency conditions such as main breaks or treatment plant shutdowns.

4.3 Modifications to Improve Water Quality in Pipes

System piping improvements to reduce DBP levels include reducing the hydraulic residence time of water in the pipes and reducing the overall disinfectant demand so that the average chlorine dose for the finished water is lowered.

The hydraulic residence time of the water in the pipes can be lowered by:

- Looping of dead-ends and re-routing of valves
- Using blow-offs
- Replacing oversized pipes with smaller diameter pipes

The overall disinfectant demand can be lowered by:

- Replacing or cleaning and lining of unlined cast iron pipes
- Flushing

4.3.1 Minimizing Hydraulic Residence Time in Pipes

4.3.1.1 Looping of Dead-Ends and Re-routing of Valves

The highest DBP concentrations in a system are often observed in dead ends with stagnant water. Water in dead ends experience long contact times for DBP formation. Construction of new pipes to loop dead ends, thereby eliminating them, can eliminate the stagnation of water and reduce residence time, decreasing the opportunity for the formation of high DBP levels. However, looping can also result in the creation of an even larger section of very slow moving water. The specific hydraulic response of a system to looping must be assessed to determine if looping will improve water flow and reduce hydraulic residence time.

Closed valves can create artificial dead-ends and lead to the development of high DBP levels. The closed valves may remain undetected until serious water quality or fire emergency problems develop. Attention should be paid to identify valves set in the wrong position and correct their setting to lower detention time in the system. A complete database of all valves in the system is essential for identifying broken or lost valves that may affect water flow. Distribution system models and/or system maps can be useful tools to identify the occurrence of dead ends and determine what type of piping or valve modifications may be needed.

4.3.1.2 Using Blow-Offs

Blow-offs can be used in areas of high water age and as an alternative to looping. A continuous or automatic intermittent blow-off can remove old water from a distribution system and pull fresh water into areas that otherwise would become stagnant. Fresh water entering an area affected by a blow-off will have had a shorter contact time between precursors and chlorine and, generally, lower DBP levels.

Continuous or automatic intermittent blow-offs can be used on a seasonal basis when DBP peaks are more likely to occur (e.g., during high water temperature periods) and can vary based on geographical regions. The need for and appropriate locations of blow-offs can be determined by analyzing distribution system historical records for low disinfectant residuals, presence of total coliforms or nusiance bacteria (fecal coliforms are not a result of water age or regrowth, they are an indicator of contamination), high heterotrophic plate counts (HPCs), and high TTHM and HAA5 concentrations. A distribution system model can be used to develop time-of-travel estimates that can help in choosing optimal blow-off locations.

4.3.1.3 Replacing Oversized Pipes

Pipe size affects water velocity and, in turn, detention time. In portions of the distribution system where pipes are oversized, the hydraulic residence times are longer than needed and can lead to formation of high DBP concentrations. The pipes in abandoned areas may still be part of the overall distribution system, but may not be required or may be too large, causing excessive hydraulic residence time. When planning replacement projects, the pipe sizes should be reassessed based on current needs, redevelopment plans, and fire protection. Where appropriate, the pipe sizes can be reduced or sections of pipes valved off if they are no longer needed to reduce the residence time of water and the potential for the formation of DBP peak concentrations. Distribution system models can be used as a tool to determine the appropriate pipe diameters.

4.3.2 Reducing Disinfectant Demand

4.3.2.1 Replacing, Cleaning, and Lining of Cast Iron Pipes

Corrosion and biofilms in unlined cast iron pipes or sediment deposits can exert a disinfectant demand that lowers chlorine residual. Utilities are often forced to increase chlorine dosages at the treatment plant or use booster chlorination to supply enough chlorine to maintain sufficient residual in the portions of their distribution system with unlined cast-iron pipe. This results in an excess of chlorine in other areas of the distribution system which can lead to DBP peaks.

Systems can reduce localized chlorine decay (and thus, reduce the overall concentration needed to maintain a residual in all parts of the system) through pipeline replacement programs. Alternatively, pipeline cleaning-and-lining can be used to reduce chlorine residual. Pipeline cleaning methods include high pressure sand blasting, various rodding methods, and chemical cleaning. Among the more common lining materials are cement-mortar, asphalt (bituminous), epoxy resins, rubber, and calcite. Cement is most commonly used, although several types of degradation of cement material can occur in the presence of acidic waters or waters that are aggressive to calcium carbonate (e.g. soft waters). For example, soft waters can progressively hydrolize calcium silicates constituents of concrete into silica gels producing soft surfaces, and leach calcium hydroxide from the cement lining (AWWA, 2002). Both of these occurrences can, in the long run, compromise the integrity of the lining.

4.3.2.2 Flushing

Frequent flushing can be an effective tool to control DBP peaks by cleaning pipes that exert chlorine demand and by lowering water age. When the chlorine demand is lowered, the chlorine dose at the treatment plant or booster disinfection facilities may be lowered, leading to lower DBP formation. There are alternative flushing methods: emergency flushing, conventional flushing of dead-ends and problem areas, and directional (also known as unidirectional) flushing.

Conventional flushing is conducted by opening hydrants (it does not include directing the flow with valves) and is considered routine distribution system maintenance. Similar to blow-offs, conventional flushing of high detention areas is an effective tool for controlling the occurrence of DBP peaks and can reduce the need for looping dead-ends. When conducted on a regular basis, conventional flushing can achieve temporary reduction of DBPs primarily by discarding old water and allowing fresher water to enter the affected area. However, with this method it is difficult to control the quality of water entering the main being flushed and it is possible that the quality of this water may not be superior to that leaving the system. In addition, conventional flushing is less than optimal in controlling other factors that can contribute to high DBP levels, since, in most pipes, the velocity of 5 to 6 ft/s required to remove sand, sediments, corrosion byproducts, and other debris is not achieved (Joseph and Pimblett, 2000).

Directional (or unidirectional) flushing is a more effective method for DBP reduction. It is conducted in a systematic manner directing the flow to enhance the flushing of the desired main. A properly designed and implemented directional flushing program can achieve water velocities to more than 5 ft/s that can scour the pipe (Joseph and Pimblett, 2000). In addition to increasing water flow in the selected main, directional flushing can reduce the impact of other factors contributing to the formation of high DBP concentrations including biofilms, the accumulation of sediments, and the build-up of corrosion For a successful directional flushing program, the order in which pipes are flushed, the hydrants that must be opened, and the valves that must be closed or opened must be carefully planned. Directional flushing should be configured to maximize water velocity when an hydrant is opened while minimizing the chance of dirty water reaching customers. Water that enters the main being flushed flows from other sections that have already been cleaned. Usually, this requires that flushing start at a source of supply and worked outward in the distribution system. Accurate maps of the system, hydraulic models, and a complete database of valves and hydrants facilitate planning and execution of directional flushing programs.

Emergency flushing (or spot flushing) is performed in response to customer complaints for color, taste, or odor problems, and in response to other water quality problems, such as insufficient disinfectant residual, evidence of nitrification, or positive coliform results. This type of flushing, is not effective for DBP control because of the small volumes of water moved and low velocities acheived.

Regardless of the flushing method implemented, systems should identify problem periods and areas using historical records. The appropriate timing of flushing can be a key factor for reducing DBP.

4.4 Booster Disinfection

Practical considerations may not allow appropriate piping or operational modifications for reducing hydraulic residence time or disinfectant demand in remote parts of the distribution system. In such cases, the use of booster disinfection can be considered to maintain a more consistent disinfectant residual throughout large distribution systems. Booster disinfection provides the opportunity to increase chlorine residual in only the areas that require it, allowing the average chlorine residual and resulting average DBP formation to be kept as low as possible.

If the majority of a distribution system is confined to an area near the plant but a small part of the system is far away from the plant, a large dose of disinfectant needs to be added at the plant to maintain the minimum required disinfectant residual in the remote part of the system. In such cases, the residual concentration in the majority of a system near the plant would be higher than what is required. The use of a booster disinfection in the remote part of the system to maintain the minimum required disinfectant residual can reduce the disinfectant dose at the plant and limit DBP formation throughout the majority the system.

It is important that the disinfectant dose added at booster stations is carefully calibrated to changes in water quality conditions and disinfection needs. Booster disinfection doses should be flow or dose paced to avoid overfeeding disinfectant. Where chlorine is overfeed, high DBPs levels can be found in water downstream of the boosting station.

4.5 Overall Strategy to Manage Water Age

Water age can contribute to the formation of high DBP concentrations within the distribution system. Generally, as long as chlorine residuals and reactive DBP precursors are present in drinking water, DBPs continue to form. Thus, the longer the contact-time between chlorine and NOM, the greater the concentration of DBPs that can be found in water as a result of the continuous formation and accumulation. This accumulation is a consequence of the formation of THMs and HAAs, and their associated chemical stabilities, which are generally quite high in disinfected drinking water as long as a significant disinfectant residual is still present (Singer and Reckhow, 1999).

In the distribution system, when the contact time between NOM and chlorine may be long, DBP levels greater than those in the finished water leaving the plant are often found. High TTHM values usually occur where the water age is the oldest. Unlike THMs, HAAs cannot be consistently related to water age because HAAs are known to biodegrade over time when the disinfectant residual is low. This might result in relatively low HAA concentrations in areas of the distribution system where disinfectant residuals are depleted.

In addition to high DBP concentrations, high water age may also result in other water quality problems including increased microbial activity, and taste and odor problems. Water age is controlled through system design and operational strategies including tank management (sections 4.1.1 and 4.1.2), flushing (section 4.3.2), looping of dead-ends (section 4.3.1) and re-routing of valves (section 4.3.1), and using blow-offs (section 4.3.1). All of these strategies have been presented in detail in relevant sections of this report. Figure 4.1 schematically illustrates a overall strategy for water age management and achievement of water quality goals.

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Appendix A

Formation and Control of Disinfection Byproducts

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A.1 Introduction

The purpose of this appendix is to identify the factors that affect formation of disinfection byproducts (DBPs) in water treatment processes and distribution systems. It is intended to serve as a tool for systems in identifying potential strategies for reducing DBP concentrations. This appendix is divided into two main sections. Section A.2 discusses the factors that affect DBP formation. Section A.3 discusses options for controlling DBP formation in general terms; it is not intended to provide guidance on implementation of DBP control strategies.

A.2 Formation of DBPs

Organic DBPs (and oxidation byproducts) are formed by the reaction between organic substances, inorganic compounds such as bromide, and oxidizing agents that are added to water during treatment. In most water sources, natural organic matter (NOM) is the major constituent of organic substances and DBP precursors. Total organic carbon (TOC) is typically used as a surrogate measure for NOM levels. The two terms are used interchangeably in much of the discussion presented here. The following major factor affecting the type and amount of DBPs formed.

- Type of disinfectant, dose, and residual concentration
- Contact time and mixing conditions between disinfectant (oxidant) and precursors
- Concentration and characteristics of precursors
- Water temperature
- Water chemistry (including pH, bromide ion concentration, organic nitrogen concentration, and presence of other reducing agents such as iron and manganese)

A summary of these factors follows.

A.2.1 Impact of Disinfection Method on Organic DBP Formation

Organic DBPs can be subdivided into halogenated and non-halogenated byproducts. Halogenated organic disinfection byproducts are formed when organic and inorganic compounds found in water react with free chlorine, free bromine, or free iodine. The formation reactions may take place in the treatment plant and the distribution system. Free chlorine can be introduced to water directly as a primary or secondary disinfectant, or as a byproduct of the manufacturing of chlorine dioxide and chloramines. Reactions between NOM, bromide and iodide ions and chlorine lead to the formation of a variety of halogenated DBPs including THMs and HAAs. Further, the oxidation of organic nitrogen can lead to the formation of DBPs containing nitrogen, such as haloacetonitriles, halopicrins, and cyanogens halides (Reckhow et al., 1990; Hoigné and Bader, 1988).

Non-halogenated DBPs may form when precursors react with strong oxidants. For example, the reaction of organics with ozone and hydrogen peroxide results in the formation of aldehydes, aldo- and keto-acids, and organic acids (Singer, 1999). Chlorine can also trigger the formation of some non-halogenated DBPs (Singer and Harrington, 1993). Many of the low molecular weight non-halogenated DBPs are biodegradable.

Trussell and Umphres (1978) reported that the presence of bromide can affect both the rate and the yield of DBPs, as well as that as the ratio of bromide to NOM (measured as total organic carbon) increases, the percentage of brominated DBPs also increases. Free chlorine and ozone oxidize bromide ion to hypobromite ion/hypobromous acid. Hypobromous acid is a more effective substituting agent than hypochlorous acid (a better oxidant) and can in turn react with NOM, forming brominated DBPs such as bromoform, and mixed bromo-chloro species (Krasner, 1999). Similarly, the presence of iodide may result in the formation of mixed chlorobromoiodomethanes byproducts (Bichsel and Von Gunten, 2000).

Studies have documented that chloramines produce significantly lower halogenated DBP levels than free chlorine, and there is no clear evidence that the reaction of NOM and chloramine leads to the formation of THMs (Singer and Reckhow, 1999; USEPA, 1999). Predictions of an empirical DBP formation model calibrated using ICR data indicated that under chloraminated conditions THMs and HAAs are formed in full-scale plants and distribution systems at a fraction of the amount that would be expected based on observations of DBP formation under free chlorine conditions. The amount of formation with chloramines varied from 5% to 35% of that calculated for free chlorine, depending on the individual DBP species (Swanson et al., 2001). The benefits of low DBP formation with chloramines are especially important for controlling formation at the extremities of the distribution system.

When chloramination is used, it is possible that DBPs might form if chlorine is added before ammonia. If the mixing process is inefficient, it is also possible that DBPs might form during the mixing of chlorine and ammonia. In this case, free chlorine might react with NOM before the complete formation of chloramines. In addition, monochloramine slowly hydrolyzes to release free chlorine in water. This free chlorine may contribute to the formation of small amounts of additional DBPs in the distribution system.

The application of chlorine dioxide does not produce significant amounts of organic halogenated DBPs unless chlorine is formed as an impurity in the generation process. Only small amounts of total organic halides (TOXs, a surrogate measure for halogenated organic compounds including THMs and HAAs) are formed. However, THMs and HAAs will form if excess chlorine is added to water to ensure complete reaction with sodium chlorite during the production of chlorine dioxide.

To date, there is no evidence to suggest that ultraviolet irradiation (UV) results in the formation of any disinfection byproducts; however, little research has been performed in this area. Most of the research regarding application of UV and DBP formation has focused on chlorinated DBP formation as a result of UV application prior to the addition of chlorine or chloramines (Malley et al., 1995). Malley, et al. conducted studies comparing the effects of UV light followed by chlorination versus chloramination. Evidence suggests UV does not affect DBP formation in either of these two cases.

Ozone does not directly produce chlorinated DBPs. However, if chlorine is added before or after ozonation mixed bromo-chloro DBPs as well as chlorinated DBPs can form. Ozone can alter the reactions characteristics of NOM and affect the concentration and speciation of halogenated DBPs when chlorine is subsequently added downstream. In waters with sufficient bromide concentrations, ozonation can lead to the formation of bromate and other brominated DBPs. Bromate, like TTHMs and HAA5, is a regulated DBP. Ozonation of natural waters also produces aldehydes, haloketones, ketoacids, carboxylic acids, and other types of biodegradable organic material. The biodegradable fraction of organic material can serve as a nutrient source for microorganisms, and should be removed to prevent microbial regrowth in the distribution system.

To date, many of the byproducts that result from chlorination or from alternative disinfectants are still unknown and unregulated. One explanation for this shortcoming is that these compounds are too polar or too high in molecular weight to be detected using conventional gas chromotography techniques (James, 1999). As more refined analytical techniques become available additional classes of disinfection byproducts may be scrutinized.

A.2.2 Disinfectant Dose

The concentration of disinfectant can affect the formation of DBPs. As the concentration of disinfectant increases the production of DBPs also increases and formation reactions continue as long as precursors (NOM) and disinfectant are present. In general, the impact of disinfectant concentration is greater during primary disinfection than during secondary disinfection. The amount of disinfectant added during primary disinfection is usually less than the long-term demand, therefore, the concentration of disinfectant is often the limiting factor while unreacted precursors are available. On the contrary, during secondary disinfection DBP formation reactions are often precursor limited since an excess of disinfectant is added to the water to maintain a residual concentration (Singer and Reckhow, 1999). In distribution systems, DBP formation reactions can become disinfectant-limited when the free chlorine residual drops to low levels. As a rule of thumb, Singer and Reckhow (1999) suggested this event takes place when the chlorine concentration drops below approximately 0.3 mg/L.

In many systems booster disinfection is applied to raise disinfectant residual concentration, especially in remote areas of the distribution system or near storage tanks where water age may be high and disinfectant residuals can be low. The additional chlorine dose applied to the water at these booster facilities may increase THM and HAA levels. Further, booster chlorination can maintain high HAA concentrations because the increased disinfection residuals can prevent the biodegradation of HAAs. However, as discussed further in Section A.3.4 booster chlorination can also be useful in decreasing DBP levels by reducing levels of secondary disinfectant needed in the finished water leaving the plant.

A.2.3 Time Dependency of DBP Formation

In general, DBPs continue to form in drinking water as long as disinfectant residuals and reactive DBP precursors are present, and the longer is the contact time between disinfectant/oxidant and NOM present, the greater is the amount of DBPs that can be formed. High concentrations of DBPs can accumulate in water. This is a consequence of the chemical stabilities of THMs and HAAs, which are generally quite high in the disinfected drinking water as long as a significant disinfectant residual is still present (Singer and Reckhow, 1999).

High THM levels usually occur where the water age is the oldest. Unlike THMs, HAAs cannot be consistently related to water age because HAAs are known to biodegrade over time when the disinfectant residual is low. This might result in relatively low HAAs concentrations in areas of the distribution system where disinfectant residuals are depleted.

In contrast to chlorination byproducts, ozonation byproducts form more rapidly, but their period of formation is much shorter than that of chlorination byproducts. This is due to the quicker dissipation of the ozone residual compared to chlorine (Singer and Reckhow, 1999).

A.2.4 Concentration and Characteristics of Precursors

The formation of halogenated DBPs is related to the concentration of NOM at the point of chlorination. In general greater DBP levels are formed in waters with higher concentrations of precursors. Studies conducted with different fractions of NOM have indicated the reaction between chlorine and NOM with high aromatic content tends to form higher DBP levels than NOM with low aromatic content. For this reason, UV absorption at 254 nm [UV_{254}], which is generally linked to the aromatic and unsaturated components of NOM, is considered a good predictor of the tendency of a source water to form THMs and HAAs (Owen et al., 1998; Singer and Reckhow, 1999). Specific ultraviolet light absorbance (SUVA) is also often used to characterize aromaticity and molecular weight distribution of NOM. This parameter is defined as the ration between UV_{254} and the dissolved organic carbon (DOC) concentration of water (Letterman et al., 1999). It should be noted, that the more highly aromatic precursors, characterized by high UV_{254}, in source waters are more easily removed by coagulation. Thus, it is the UV_{254} measurement immediately upstream of the point(s) of chlorination within a treatment plant that is more directly related to THM and HAA formation potential.

A.2.5 Water Temperature

The rate of formation of THMs and HAAs increases with increasing temperature. Consequently, the highest THM and HAA levels may occur in the warm summer months. However, water demands are often higher during these months, resulting in lower water age within the distribution system which helps to control DBP formation. Furthermore, high temperature conditions in the distribution system promote the accelerated depletion of residual chlorine, which can mitigate DBP formation and promote biodegradation of HAAs unless chlorine dosages are increased to maintain high residuals (Singer and Reckhow, 1999). For these reasons, depending on the specific system, the highest THM and HAA levels may be observed during months which are warm, but not necessarily the warmest.

Seasonal trends affect differently where high THM and HAA concentrations might be found. For example, when water is colder, microbial activity is typically lower and DBP formation kinetics are slower. Under these conditions, the highest THM and HAA concentrations might appear coincident with the oldest water in the system. In warmer water, the highest HAA concentrations might appear in fresher water, which is likely to contain higher disinfectant residuals that can prevent the biodegradation of HAAs.

A.2.6 Water pH

In the presence of NOM and chlorine, THM formation increases with increasing pH, whereas the formation of HAAs and other DBPs decrease with increasing pH. The increased THM production at high pH is likely promoted by base hydrolysis (favored at high pH). HAAs are not sensitive to base hydrolysis but their precursors are. Consequently, pH can alter their formation pathways leading to decreased production with increasing pH (Singer and Reckhow, 1999).

The major byproducts of ozonation are not affected by base hydrolysis. However, pH can play a role by affecting the rate of decomposition of ozone to hydroxyl radical. The decomposition of ozone accelerates as pH increases. This occurrence is thought to be responsible for the decrease of some byproducts (e.g., aldeydes) and the increase of others (e.g., carbonyl byproduct and total organic halides; Singer and Reckhow, 1999). Water pH affects the balance of hypobromite and hypobromous acid formation during the ozonation of waters containing significant concentrations of bromides. At low pH, the equilibrium shifts to the less reactive hypobromous acid. Consequently, the overall formation of bromate decrease as pH decrease (Singer and Reckhow, 1999). On the other hand, Song et al. (1997) suggested that lower pHs favor the formation of TOX (most likely TOBr) during ozonation. Singer and Reckhow (1999) attributed this occurrence to the concurrent suppressed decomposition of ozone, changes in the speciation of the oxidized bromine and the hydrolysis of brominated byproducts.

A.3 Control of DBPs

Alternatives to minimize the formation of DBPs focus on the removal of precursors during treatment, modifications of the oxidation and disinfection processes, control of oxidants dose and residual, reduction of the residence time in the distribution system, and removal of

DBPs after formation. Because DBPs are difficult to remove after they have formed, control strategies typically focus on the first four methods.

A.3.1 Improving Precursors Removal

The removal of organic precursors can be improved by optimizing coagulation practices or by employing advanced precursor removal processes such as granular activated carbon (GAC) adsorption, membrane filtration, or biofiltration.

The process of improving the removal of NOM during the coagulation process is defined as *enhanced coagulation*. Greater NOM removal can be obtained with adjustments in treatment practice, specifically pH reduction and increased coagulant dosage. The coagulation of NOM appears to be most efficient in the 5 to 6 pH range.

A number of sources have documented that granular activated carbon (GAC) and nanofiltration (NF) can be more effective DBP precursor removal processes than conventional coagulation treatment (McGuire et al., 1989; Owen et al., 1998; Snoeyink et al., 1999; Jacangelo, 1999; Taylor and Wiesner, 1999; and references therein). Reverse osmosis (RO) can also be very effective for removing precursors. However, when precursor removal (as opposed to demineralization) is the primary treatment objective, NF is usually preferred to RO because of its lower operating pressure and associated costs. Both NF and RO can remove bromide (Jacangelo, 1999) while GAC does not appear to remove bromide to any significant extent (Snoeyink et al., 1999)

Biofiltration can be used to remove a portion of the NOM from water by converting it into inorganic carbon (CO_2) and it is considered a viable treatment alternative for precursors removal (Hozalski and Bouwer, 1999). In general, the ideal location for a biofilter is in a rapid media filter and its performance can vary from one plant to another depending on factors such as NOM source and characteristics, use of ozone for preoxidation, residence time in the biofilter, media type, and water temperature (Hozalski and Bouwer, 1999).

Watershed management practices as well as timing and location of withdrawals can also achieve reductions of DBP precursors in the raw water. The extent of the benefit of implementing this strategy is site specific.

A.3.2 Disinfection and Oxidation Methods and Disinfectant Dose

Chlorination generally produces the highest THM and HAA levels. Other oxidation alternatives to chlorine (e.g., use of ozone, chloramines, chlorine dioxide, potassium permanganate, and UV radiation) can be used to minimize the formation of TTHM and HAAs. Generally, decreasing the disinfectant dose and residual reduces DBP levels (see Section A.2). However, when considering disinfectant changes it is important to consider disinfection needs and maintain the appropriate CT for disinfection. Some alternative disinfectants cannot be used for secondary disinfection. A detailed discussion of alternative disinfectants can be found in the *Alternative Disinfectants and Oxidants Guidance Manual* (USEPA, 1999, 815-R-99-014).

A.3.3 Shifting the Point of Disinfectant Application

Shifting the point of disinfectant application from upstream to downstream of the coagulation/settling process can significantly reduce the formation of DBPs for two main reasons: the amount of precursors is reduced prior to disinfectant addition, and (particularly for chlorination) the contact time between disinfectant and NOM is reduced. The implementation of this strategy must, however, take into account disinfection needs. Adequate contact time must be always provided after the application of disinfectant to achieve the desired inactivation of microorganisms.

A.3.4 Control of DBP Formation in the Distribution System

For systems maintaining free chlorine residual, significant DBP formation can occur in the distribution system. A long detention time in the distribution system, the presence of NOM in the finished water and the presence of free chlorine residual can promote this occurrence. It is not uncommon that water leaving a treatment plant with low THM and HAA concentrations is found to have high levels of these compounds in the distribution system. Generally, application of secondary disinfectant (particularly chlorine) to form and maintain a residual in the distribution system results in DBP formation. Implementation of distribution system water quality monitoring, minimization of "dead ends," optimization of storage tank utilization, execution of effective planned system flushing and management of water age can minimize DBP formation.

In some cases, booster chlorination has also been used to control disinfectant application and minimize DBP formation. For example, where the majority of the distribution system is in a confined area near the plant, but a small part is far away from the plant a large dose of disinfectant would be required to maintain a residual in the extreme part of the system. A much higher residual concentration than is needed would be present in the majority of the system. Thus, booster disinfection in the extreme part of the system could dramatically reduce the disinfectant dose at the plant and reduce DBP formation through the system. However, it must also be noted that in areas following booster disinfection facilities, the residence time is often long. If conditions favor formation (i.e. water age, temperature, NOM concentration) the additional disinfectant added might lead to the formation of high TTHM and HAA levels. Increased disinfectant residual can also prevent biodegradation of HAA, further increasing distribution system levels. The use or addition of booster disinfection requires careful consideration in any DBP control strategy.

A.3.5 Assessing DBP Formation and Control with the WTP Model

If a utility determines, based upon distribution system monitoring, that the DBP levels in their system need to be reduced, they may consider implementing treatment changes in their water treatment plant. To evaluate the potential impact of treatment changes on distribution system DBP levels prior to the implementation of these changes, a system may consider using the Water Treatment Plant Simulation Model (WTP Model) as a preliminary tool. This model was initially developed to support the DBP rule making process and was later revised to improve the predictive accuracy using data collected under the Information Collection Rule (ICR). The WTP Model consists of empirical models developed from bench-, pilot-, and full-scale treatability data. The majority of the predictive algorithms have been verified with independent data sets (Solarik et al., 1999), and many key algorithms have been calibrated using ICR data from full-scale surface water treatment plants (Swanson et al., 2001). A description of the original model was presented by Harrington, et al. (1992) and is available from the USEPA's Technical Support Center in Cincinnati. The WTP Model was developed as a central tendency model, and was not specifically designed to yield site specific predictions. However, a significantly improved form of the WTP Model (Version 2.0) currently under review by the agency will facilitate site specific calibration of the model. Extensive experiments to determine water quality characteristics are required to validate site specific model use.

In addition to simulating the effects of traditional surface water treatment processes, such as coagulation (or lime softening), flocculation, sedimentation, and filtration, the WTP Model supports many advanced disinfection and DBP control processes, such as:

- Enhanced coagulation
- GAC adsorption
- Microfiltration/ultrafiltration
- Nanofiltration/reverse osmosis
- Ozonation
- Biological filtration
- Chlorine dioxide addition

The WTP Model generates predictions of bromate formation during ozonation, chlorite formation during chlorine dioxide addition, and THM, HAA, and TOX formation due to free chlorine and chloramine addition. These predictions are generated at the effluent of each unit treatment process and within the distribution system (detention times are required as inputs). The WTP Model also calculates CT values achieved for the various disinfectants used during treatment and log inactivation values for virus, *Giardia*, and *Cryptosporidium*. Thus, the program can be used to evaluate the relative effects of treatment modifications on disinfection and DBP formation.

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Appendix B

Changes in Source Water Quality

Significant Excursions Identified Using the “Maximum Concentration Approach”

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The first part of this appendix includes general system information and a summary of TTHM and HAA5 data that resulted in Elm City having to perform a significant excursion evaluation. This information is not required as part of the documentation of a significant excursion. <u>Only the Significant Excursion Report is required to be completed by systems that experience a significant excursion.</u>

This appendix is provided as an example of a system in which changes in source water quality led to a DBP Significant Excursion. Possible strategies to reduce excursions are presented in Chapter 4, but they are not to be included in the identification and documentation process. Appendices C through E provide similar examples for systems in which changes in treatment plant operations, changes in distribution system, and multiple causes resulted in a significant excursion.

This example assumes the state has chosen to use 100 μg/L TTHM and 75 μg/L HAA5 as the trigger levels for determining that a significant excursion has occurred and that a significant excursion evaluation is required.

<u>Background Information for this Example</u>

System Description:

<u>General system characteristics</u>:

Service area: Elm City plus surrounding suburban areas
Production: Annual average daily demand 15 MGD

<u>Source Water Information:</u>

Hardwood Lake (surface water)
- pH: from 6.9 to 7.5
- Alkalinity: from 82 to 98 mg/L as $CaCO_3$
- TOC: from 2.1 to 4.0 mg/L as C
- Bromide: from 0.04 to 0.1 mg/L
- Turbidity: 1 to 100 ntu

Softwood River (surface water)
- pH: from 6.8 to 7.9
- Alkalinity: from 77 to 94 mg/L as $CaCO_3$
- TOC: from 1.6 to 9.4 mg/L as C
- Bromide: from 0.03 to 0.1 mg/L
- Turbidity: 2 to 115 ntu

Treatment Provided:

Hardwood, conventional (15 MGD design, 7.5 MGD average)
Softwood River, conventional with GAC (20 MGD design, 7.5 MGD average)
Primary and residual disinfection: Chlorine/chlorine at both plants

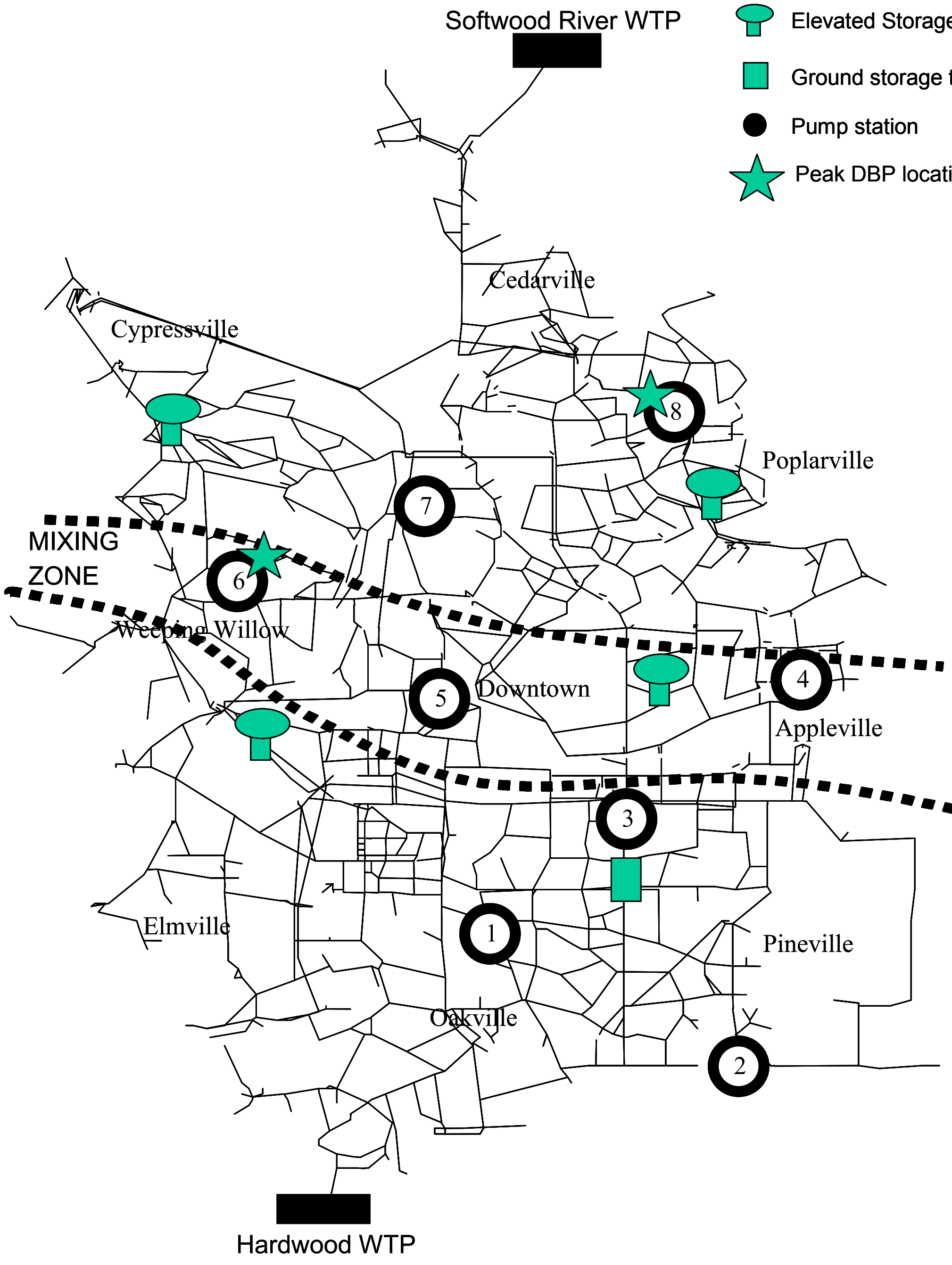
Summary of Stage 2 DBPR Monitoring Locations:

Table B.1 summarizes the Stage 2 DBPR monitoring locations used by Elm City. Sample locations are marked in the distribution system schematic presented in Figure B.1.

Table B.1 Stage 2 DBPR Monitoring Locations

Location	Description
Location #1	Hardwood Plant - average residence time
Location #2	Hardwood Plant - high TTHM
Location #3	Hardwood Plant - high HAA5
Location #4	Hardwood/Softwood Mix Zone - high TTHM
Location #5	Hardwood/Softwood Mix Zone - high TTHM
Location #6	Hardwood/Softwood Mix Zone - high TTHM
Location #7	Softwood Plant - average residence time
Location #8	Softwood Plant - high HAA5

Figure B.1 Schematic of Elm City Distribution System and Stage 2 DBPR Monitoring Locations



DBP Excursion Investigation:

During the last sampling period which took place in September 2004, Elm City experienced unusually high TTHM values (relative to the LRAA) at two monitoring locations

(#6, #8). Similarly, unusually high HAA5 values were detected at one monitoring location (#8). DBP data from the previous year and most recent sampling period (five quarters total) are presented in Table B.2.

Table B.2 TTHM and HAA5 Monitoring Data

Location	**TTHM (ug/L)**				**HAA5 (ug/L)**			
	Quarterly Pre-Sept. 2004 Data[1]	LRAA Pre-Sept. 2004 Avg.	Sept. 2004 Data	LRAA Sept. 2004 Avg.	Quarterly Pre-Sept. 2004 Data[1]	LRAA Pre-Sept. 2004 Avg.	Sept. 2004 Data	LRAA Sept. 2004 Avg.
#1	54, 67, 58, 75	65	63	67	52, 37, 30, 41	40	52	40
#2	68, 68, 55, 69	63	72	64	38, 45, 28, 19	33	39	33
#3	66, 52, 71, 72	64	81	68	41, 46, 45, 39	43	51	46
#4	50, 55, 51, 61	55	78	62	42, 43, 38, 34	39	66	45
#5	34, 48, 55, 50	44	79	55	32, 43, 55, 38	42	58	49
#6	44, 62, 58, 60	49	**<u>121</u>**	66	45, 33, 41, 40	40	72	47
#7	40, 41, 37, 46	41	77	50	31, 38, 28, 19	27	59	37
#8	49, 39, 50, 76	52	**<u>146</u>**	76	43, 39, 41, 45	42	**<u>98</u>**	56

[1]Data for sampling conducted on September 2003, December 2003, March 2004 and June 2004. Data relevant to peak excursions are **bold and underlined**.

Unusually high TTHM samples were collected at locations #6 and #8, and unusually high HAA5 samples were collected at location #8. The results are significantly higher than both the LRAA at those locations for the previous 12-month period and the historic TTHM and HAA5 values at those locations for the years 1999-2003 (see Significant Excursions Evaluation Report). Significant excursion were identified when DBP levels exceeded 100 µg/L TTHM or 75 µg/L HAA5. All of the monitoring locations affected by high DBP are located in the area served by the Softwood plant or in the mixing zone. The city staff has reason to believe that a water quality change that has occurred in Softwood River caused the increase in DBPs.

Significant Excursion Evaluation Report Page 1	Report date: October 16th, 2004 Report prepared by: Robert Doe, P.E. System name: Elm City

1) When was the significant excursion sample(s) collected? What were the TTHM and HAA5 concentrations?

Location No.	# 6	# 8		
Location description	Hardwood/Soft-wood Mix Zone – High TTHM	Softwood plant – High HAA5		
Sample collection date	Sept. 4th, 2004	Sept. 4th, 2004		
Sample collection time	2 p.m.	3 p.m.		
TTHM LRAA Concentration (ug/L)	66	76		
TTHM Concentration (ug/L)	121	146		
HAA5 LRAA Concentration (ug/L)		56		
HAA5 Concentration (ug/L)		98		

Note: Attach additional sheets if you observed more than four significant excursions during this round of sampling.

2) Where did the excursion(s) occur? Attach a schematic of your system, sketch your system in the space below, or have a schematic of your system available to review with your state at the time of your next sanitary survey. Indicate the location(s) of the significant excursion(s) on your schematic.

Location #6 – This sample location is a faucet at a connection located in Weeping Willow - a zone of the distribution system that has been recently developed. This connection is located downstream from a chlorine booster station. Water in this area is generally a mix of water from the Hardwood and Softwood River Plants.

Location #8 – This sampling location is in an area that receives water from the Softwood Plant. Samples are collected at a hose bib near the first house on the cul-de-sac (which has 12 homes total). For this example, the location of these sample locations is illustrated in Figure B.1

Significant Excursion Evaluation Report Page 2	Report date: October 16th, 2004

3) Attach (or provide in the Supplemental Data Form) all available water quality data for the round of sampling in which the significant excursion occurred. At a minimum, include all TTHM and HAA5 results from the sampling period. You should also consider including pH, temperature, alkalinity, TOC, disinfectant residual, and any other data that you think would be useful.

   a) Were there any unusual circumstances associated with this round of sampling?

      Yes____ No_X__

      If yes, please explain.

   b) Were all analytical QA/QC measures met?

      Sample preservation Yes _X__ No____

      Sample holding time Yes _X__ No____

      Other ____________________

      ____

      ____

      If no, please explain.

4) Attach (or provide in the Supplemental Data Form) historical TTHM and HAA5 data for the location(s) at which the significant excursion(s) occurred. Provide at least three years of data, if available.

Report date: October 16th, 2004

5) What caused your excursion(s) to occur?

Sections A through F starting on page 4 can help you determine the possible cause(s) of your excursion. Please note there may be more than one factor which resulted in your excursion.

Section A: Source water quality change
Section B: Process upset at treatment plant
Section C: Planned change or maintenance activities at plant
Section D: Planned distribution system operations or maintenance activities
Section E: Unplanned events in distribution system

If you already suspect a cause, go directly to that section. If you read Sections A through E and are unable to determine a cause of your excursion, then complete Section F.

Consecutive systems should also contact their wholesaler to identify the cause(s) of the significant excursion(s).

6) List steps taken or planned to reduce DBP peak levels.

We are considering adjustments of the coagulation processes to improve TOC removal including: increasing the coagulant dose, evaluation of alternative coagulants, evaluation of coagulant aids, lowering the pH of coagulation, use of a pre-oxidant (permanganate or chlorine dioxide), and use of PAC.

Significant Excursion Evaluation Report

Page 4

Report date: October 16th, 2004

A. Source Water Quality Changes

- Did any of the events listed below take place before the DBP excursion to cause TOC levels to increase?
  - Heavy rain fall
  - Flooding
  - Spring snow-melt/runoff
  - Significant decrease in rainfall or source flow
  - Algae bloom

- Did any of the events listed below take place before the DBP excursion to cause bromide levels to increase?
  - Significant decrease in rainfall or source flow
  - Brackish or seawater intrusion

- Did pH and/or alkalinity significantly change?

- If two or more supplies are used, was a greater portion of water drawn from the one with higher TOC?

- Was raw water stored for an unusually long period of time resulting in a significant increase in water temperature?

Conclusions:

Did source water quality changes cause or contribute to your significant excursion(s)?

Yes __X__ No ______

If yes, please explain:

The most probable cause of the DBP excursion noted during the September 2004 sampling even was a rapid increase of the organic matter concentration in the Softwood River. Following two days of heavy rainfall the TOC measured in the plant influent increased from 2.7 mg/L to 8.4 mg/L. At the same time, turbidity of the source water also increased from 5 ntu to a maximum of 98 ntu. The coagulant (ferric chloride) dose was increased from 20 mg/L to 75 mg/L to match water quality changes. For the duration of this high turbidity/ high NOM event, the pH of coagulation was maintained between 61. and 6.3. The higher coagulant dose prevented any significant increases of turbidity in the settled water, but the concentration of TOC in the plant effluent increased from 1.8 mg/L to 3.8 mg/L. Jar testing conducted at the time of the event indicated that a further increase of the coagulant dose (dosages up to 120 mg/L were tested) would have not significantly improved TOC removal under the pH conditions presently used to conduct the coagulation process.

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

B. Process Upset at Treatment Plant

- Was raw water stored for an unusually long time, providing additional contact time for DBP formation after prechlorination?

- Were there changes in coagulation practices?
  - Were there any changes or malfunctions of the coagulation process in the days leading to the excursion?
  - Were the coagulant dose and pH properly adjusted for incoming source water conditions?

- Were there changes in chlorination practices?
  - Were there any changes in chlorine dose at any location in the plant?
  - Were there changes in plant flow that may have resulted in longer than normal residence time at any location in the plant?
  - Did the pH change at the point of chlorine addition?

- Were there changes in settling practices?
  - Was there excess sludge build-up in the settling basin that may have carried over to the point of disinfectant addition?
  - Was there any disruption in the sludge blanket that may have resulted in carryover to the point of disinfection?

- Were there changes in filtration practices?
  - Have filter run times been changed to meet raw water quality changes?
  - Were there any spikes in individual filter effluent turbidity (which may indicate particulate or colloidal TOC breakthrough) in the days leading to the excursion?
  - Did chlorinated water sit in the filter for an extended period of time?
  - Were all filters run in a filter-to-waste mode during initial filter ripening?
  - Were any filters operated beyond their normal filter run time?
  - If GAC filters are used: Is it possible the adsorptive capacity of the GAC bed was reached before reactivation occurred?
  - If biological filtration is used: Were there any process upsets that may have resulted in breakthrough of TOC (particularly biodegradable TOC)?

- Were there changes in plant flow that may have resulted in an unusually high residence time in the clearwell on the days prior to the excursion?
  - For example, a temporary plant shutdown.

Continued on next page

Significant Excursion Evaluation Report
Page 6

Report date: October 16th, 2004

B. Process Upset at Treatment Plant (Continued)

Conclusions:

Did a process upset in the treatment plant cause or contribute to your significant excursion(s)?

Yes____ No __X__

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

C. Planned Change or Maintenance Activities for the Treatment Plant

- Was there a recent change (or addition) of pre-oxidant?
- Was there any maintenance in the basin that may have stirred sludge from the bottom of the basin and caused it to carry over to the point of disinfectant addition?
- Did you change the type or manufacturer of the coagulant?
- Were there any changes in disinfection practices in the days prior to the excursion?
  - For example, a switch from chloramines to free chlorine for burnout period.
  - Discontinuation of ozone which forms very little TTHM.
- Was a filter(s) taken off-line for an extended period of time that caused the other filters to operate near maximum design capacity and creating the conditions for possible breakthrough?
- Were any pumps shut down for maintenance, leading to changes in flow patterns or hydraulic surges?

Conclusions:

Did a planned maintenance or operational activity in the treatment plant cause or contribute to your significant excursion(s)?

Yes_____ No __X__

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

D. Planned Distribution System Operations or Maintenance Activities

- Was a tank drained for cleaning or other maintenance?
  - Was the tank drained to waste or to the distribution system?
  - Was a larger volume than normal drained to the distribution system?
- If booster disinfection is used, was the booster disinfectant dose higher than the normal booster disinfectant dose for that season?
- Were there any system maintenance activities in the days prior to DBP excursion? Including:
  - Repairing mains or installing new mains
  - Closure of valves to isolate sections of pipes
- Were the pipes flushed properly or were the appropriate valves re-opened after work was completed?
- Did any pump or pipeline maintenance occur that would have changed the flow pattern in the area the sample was drawn from?
  - Change in flow can cause water in stagnant areas to be drawn into another area.
- Did any pipeline replacement occur?
  - Disinfecting piping in contact with drinking water could result in a high concentration of chlorine entering the distribution system and thus increase DBPs.

Conclusions:

Did a planned distribution system maintenance or operational activity cause or contribute to your significant excursion(s)?

Yes _____ No __X__

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Significant Excursion Evaluation Report

Report date: October 16th, 2004

E. Unplanned Distribution System Events

- Were there increases in demand that caused older water in storage tanks to be drawn into the system?
  - Were there any major fire events?
  - Did one or more storage tank have greater than average drawdown preceding the time of DBP peak excursion?

- Were there decreases in demand that resulted in longer than normal system residence times?
  - Were there any large customers off-line?

- Did any main breaks occur causing changes in flow patterns in the influence area of the sample location?

- If you collect water temperature inside storage tanks, was the temperature inside the tank higher than normal for the season?

- Were any storage tanks hydraulically locked out of the system for an extended period and then used preceding the time of DBP peak excursion?

- Did changes in overall water demand cause a change in water demand patterns in the vicinity of dead ends and/or stagnant zones in the system?

- Were there large variations in localized system pressures that were different from the normal pressure range that could have caused a change in water demand patterns in the vicinity of dead ends and/or stagnant zones in the system?

Conclusions:

Did an unplanned distribution system maintenance or operational activity cause or contribute to your significant excursion(s)?

Yes____ No __X___

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Report date: October 16th, 2004

F. If you were unable to identify the cause of your significant excursion(s) after reviewing Sections A through E, are you able to identify another potential cause of your increase in DBP concentrations? Explain.

Note: *If you are unable to determine the cause of your excursion you may wish to consider:*

- More frequent raw water temperature monitoring.
- More frequent raw water TOC monitoring.
- Increased disinfectant residual monitoring in the distribution system.
- Tracer studies to characterize distribution system water age.
- Development of a hydraulic model to characterize the distribution system.

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Supplemental Data Form for the Significant Excursion Evaluation Report

Report date: October 16th, 2004

Report prepared by: Robert Doe, P.E.

System name: Elm City

1) Water quality data from significant excursion sampling period.

Location No.	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**
Location Name								
TTHM (ug/L)	63	72	81	78	55	***121***	77	***146***
HAA5 (ug/L)	52	39	51	66	58	72	59	***98***
Free Chlorine (mg/L)	1.8	1.3	NA	NA	NA	1.1	NA	0.8
Total Chlorine (mg/L)	2.1	1.8	NA	NA	NA	1.8	NA	1.2
pH	7.9	8.0	8.3	8.1	7.8	8.3	7.5	8.2

2) Supplemental data from each treatment facility:

Plant #1: Hardwood Plant
Raw Water Temperature: NA

Plant Effluent Water Temperature: 20 °C

Raw Water TOC: 2.2 mg/L (Avg. <2.0mg/L)

Other Data:

Plant #2: Softwood Plant
Raw Water Temperature: NA

Plant Effluent Water Temperature: 20 °C

Raw Water TOC: 3.8 mg/L (Avg.<2.0mg/L)

Other Data: Inf. turb. 98 ntu (Avg. <20 ntu)

3) Historical TTHM and HAA5 data at significant excursion sampling locations.

TTHM Data (ug/L)

Monitoring Location	# 5	# 6	# 7	# 8
Date - 1999	43	58	45	49
Date - 2000	51	49	56	64
Date - 2001	46	69	41	69
Date - 2002	48	61	73	66
Date - 2003	34	44	53	79
Avg. 99-03	44	56	54	65

HAA5 Data (ug/L)

Monitoring Location	# 8	#	#	#
Date - 1999	56			
Date - 2000	47			
Date - 2001	33			
Date - 2002	34			
Date - 2003	43			
Avg. 99-03	43			

Attach additional sheets if necessary

Appendix C

Changes in Treatment Plant Operation

Significant Excursions Identified Using the "Maximum Concentration Approach"

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The first part of this appendix includes general system information and a summary of TTHM and HAA5 data that resulted in Elm City having to perform a significant excursion evaluation. This information as part of the documentation of a significant excursion. Only the Significant Excursion Report is required to be completed by systems that experience a significant excursion.

This appendix is provided as an example of a system in which changes in treatment plant operations led to a DBP Significant Excursion. Possible strategies to reduce excursions are presented in Chapter 4, but they are not to be included in the identification and documentation process. Appendices B, D, and E provide similar examples for systems in which changes in source water quality, changes in distribution system, and multiple causes resulted in a significant excursion.

This example assumes the state has chosen to use 100 μg/L TTHM and 75 μg/L HAA5 as the trigger levels for determining that a significant excursion has occurred and that a significant excursion evaluation is required.

Background Information for this Example

System Description:

General system characteristics:

Service area: Elm City plus surrounding suburban areas
Production: Annual average daily demand 15 MGD

Source Water Information:

Hardwood Lake (surface water)
- pH: from 6.9 to 7.5
- Alkalinity: from 82 to 98 mg/L as $CaCO_3$
- TOC: from 2.1 to 4.0 mg/L as C
- Bromide: from 0.04 to 0.1 mg/L
- Turbidity: 1 to 100 ntu

Softwood River (surface water)
- pH: from 6.8 to 7.9
- Alkalinity: from 77 to 94 mg/L as $CaCO_3$
- TOC: from 1.6 to 9.4 mg/L as C
- Bromide: from 0.03 to 0.1 mg/L
- Turbidity: 2 to 115 ntu

Treatment Provided:

Hardwood, conventional (15 MGD design, 7.5 MGD average)
Softwood River, conventional with GAC (20 MGD design, 7.5 MGD average)
Primary and residual disinfection: Chlorine/chlorine at both plants

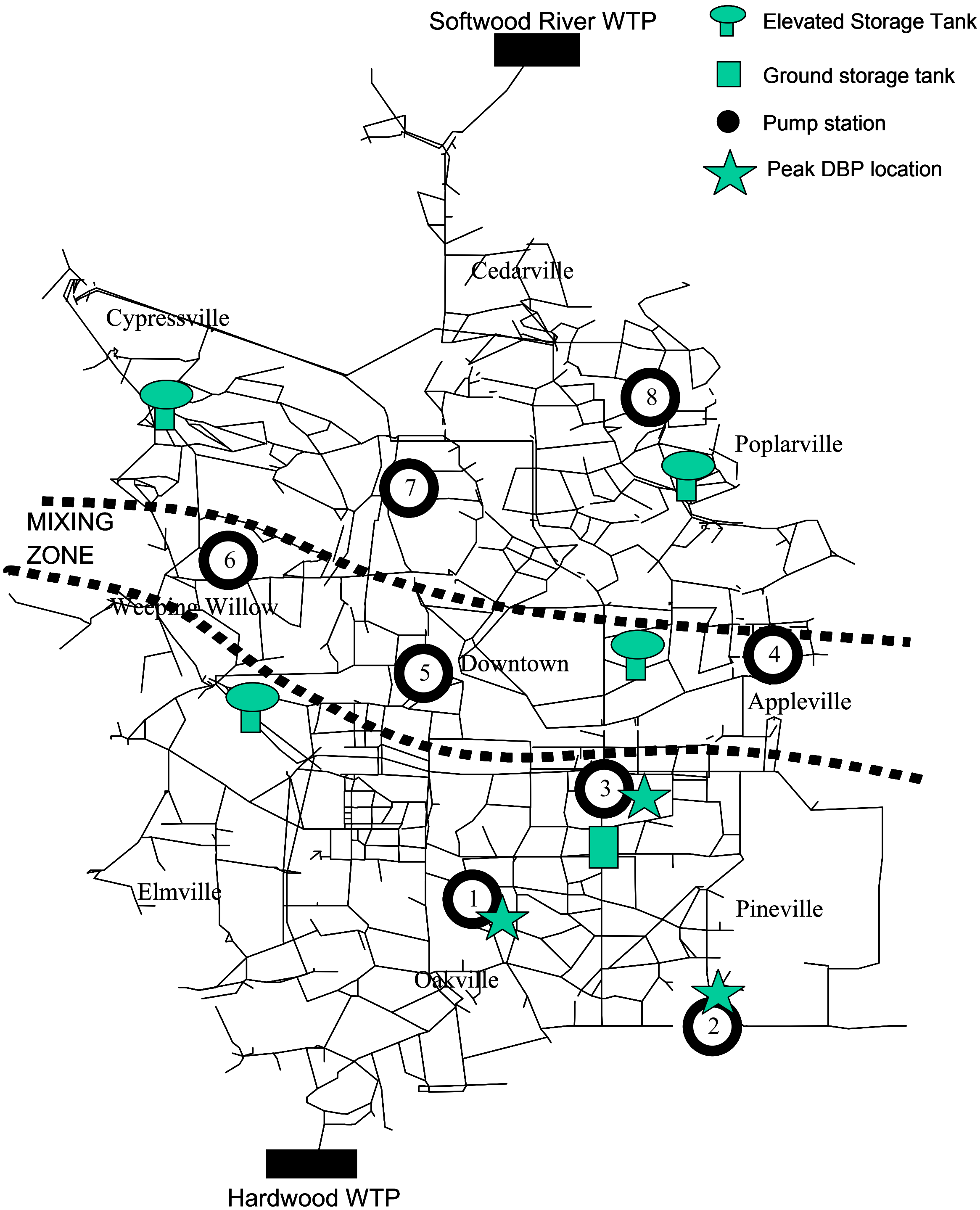
Summary of Stage 2 DBPR Monitoring Locations:

Table C.1 summarizes the Stage 2 DBPR monitoring locations used by Elm City. Sample locations are marked in the distribution system schematic presented in Figure C.1.

Table C.1 Stage 2 DBPR Monitoring Locations

Location	Description
Location #1	Hardwood Plant - average residence time
Location #2	Hardwood Plant - high TTHM
Location #3	Hardwood Plant - high HAA5
Location #4	Hardwood/Softwood Mix Zone - high TTHM
Location #5	Hardwood/Softwood Mix Zone - high TTHM
Location #6	Hardwood/Softwood Mix Zone - high TTHM
Location #7	Softwood Plant - average residence time
Location #8	Softwood Plant - high HAA5

Figure C.1 Schematic of Elm City Distribution System and Stage 2 DBPR Monitoring Locations



DBP Excursion Investigation:

During the last sampling period which took place in September 2004, Elm City experienced unusually high TTHM values (relative to the LRAA) at five monitoring locations (#4, #5, #6, #7, #8). Similarly, unusually high HAA5 values were detected at two monitoring locations (#7 and #8). DBP data from the previous year and most recent sampling period (five quarters total) are presented in Table C.2.

Table C.2. TTHM and HAA5 Monitoring Data

	TTHM (ug/L)				HAA5 (ug/L)			
Location	Quarterly Pre-Sept. 2004 Data[1]	LRAA Pre-Sept. 2004 Avg.	Sept. 2004 Data	LRAA Sept. 2004 Avg.	Quarterly Pre-Sept. 2004 Data[1]	LRAA Pre-Sept. 2004 Avg.	Sept. 2004 Data	LRAA Sept. 2004 Avg.
#1	54, 67, 58, 75	65	**<u>118</u>**	74	52, 37, 30, 41	40	**<u>84</u>**	48
#2	68, 68, 55, 69	63	**<u>145</u>**	77	38, 45, 28, 19	33	**<u>75</u>**	42
#3	66, 52, 71, 72	64	**<u>122</u>**	74	41, 46, 45, 39	43	58	47
#4	50, 55, 51, 61	55	82	60	42, 43, 38, 34	39	54	42
#5	34, 48, 55, 50	44	68	48	32, 43, 55, 38	42	37	43
#6	44, 62, 58, 60	49	70	53	45, 33, 41, 40	40	53	42
#7	40, 41, 37, 46	41	58	46	21, 38, 28, 19	27	29	29
#8	49, 39, 50, 76	52	78	56	43, 39, 41, 45	42	49	44

[1]Data for sampling conducted on September 2003, December 2003, March 2004 and June 2004. Data relevant to peak excursions are **<u>bold and underlined</u>**.

Unusually high TTHM samples were collected at locations #1, #2, and #3, and unusually high HAA5 samples were collected at locations #1 and #2. The results are significantly higher than both the LRAA at those locations for the previous 12-month period and the historic TTHM and HAA5 values at those locations for the years 1999-2003 (see Significant Excursions Evaluation Report). Significant excursion were identified when DBP levels exceeded 100 µg/L TTHM or 75 µg/L HAA5. All of the monitoring locations affected by high DBP are located in the area served by the Hardwood plant. The city staff has reason to believe that a process change occurred during treatment operations at the Hardwood plant caused this increase in DBP levels.

Significant Excursion Evaluation Report

Page 1

Report date: October 16th, 2004

Report prepared by: Ronald Doe, P.E.

System name: Elm City

1) When was the significant excursion sample(s) collected? What were the TTHM and HAA5 concentrations?

Location No.	# 1	# 2	# 3	# ___
Location description	Hardwood Plant - average residence time	Hardwood Plant - high TTHM	Hardwood Plant - high HAA5	
Sample collection date	Sept. 4th, 2004	Sept. 4th, 2004	Sept. 4th, 2004	
Sample collection time	1 p.m.	3 p.m.	11 a.m.	
TTHM LRAA Concentration (ug/L)	74	77	74	
TTHM Concentration (ug/L)	118	145	122	
HAA5 LRAA Concentration (ug/L)	48	42		
HAA5 Concentration (ug/L)	84	75		

Note: Attach additional sheets if you observed more than four significant excursions during this round of sampling.

2) Where did the excursion(s) occur? Attach a schematic of your system, sketch your system in the space below, or have a schematic of your system available to review with your state at the time of your next sanitary survey. Indicate the location(s) of the significant excursion(s) on your schematic.

Location #1 – Represents average residence time of water leaving the Hardwood Plant. It is located in the Oakville neighborhood. There are no storage facilities between the treatment plant and this location.

Location #2 – Sample tap is a hose bib at a building located in Pineville in a zone of the distribution system with water age greater than average. Water in this area is from the Hardwood Plant.

Location #3 – This location is located in the Downtown area. Water is primarily from the Hardwood Plant. A ground storage tank is near this location.

The location of these sample locations is illustrated in Figure C.1.

Significant Excursion Evaluation Report
Page 2

Report date: October 16th, 2004

3) Attach (or provide in the Supplemental Data Form) all available water quality data for the round of sampling in which the significant excursion occurred. At a minimum, include all TTHM and HAA5 results from the sampling period. You should also consider including pH, temperature, alkalinity, TOC, disinfectant residual, and any other data that you think would be useful.

   a) Were there any unusual circumstances associated with this round of sampling?

      Yes____ No__X__

      If yes, please explain.

   b) Were all analytical QA/QC measures met?

      Sample preservation Yes__X__ No_____

      Sample holding time Yes__X__ No_____

      Other ____________________

      ____

      ____

      If no, please explain.

4) Attach (or provide in the Supplemental Data Form) historical TTHM and HAA5 data for the location(s) at which the significant excursion(s) occurred. Provide at least three years of data, if available.

Significant Excursion Evaluation Report
Page 3

Report date: October 16th, 2004

5) What caused your excursion(s) to occur?

Sections A through F starting on page 4 can help you determine the possible cause(s) of your excursion. Please note there may be more than one factor which resulted in your excursion.

Section A: Source water quality change
Section B: Process upset at treatment plant
Section C: Planned change or maintenance activities at plant
Section D: Planned distribution system operations or maintenance activities
Section E: Unplanned events in distribution system

6) List steps taken or planned to reduce DBP peak levels.

Plan to calibrate standby pumps for future maintenance of coagulant process feed pumps. Considering improvements to coagulant process monitoring (daily verification with pump catch, streaming current monitoring).

Report date: October 16th, 2004

A. Source Water Quality Changes

- Did any of the events listed below take place before the DBP excursion to cause TOC levels to increase?
  - Heavy rain fall
  - Flooding
  - Spring snow-melt/runoff
  - Significant decrease in rainfall or source flow
  - Algae bloom

- Did any of the events listed below take place before the DBP excursion to cause bromide levels to increase?
  - Significant decrease in rainfall or source flow
  - Brackish or seawater intrusion

- Did pH and/or alkalinity significantly change?

- If two or more supplies are used, was a greater portion of water drawn from the one with higher TOC?

- Was raw water stored for an unusually long period of time resulting in a significant increase in water temperature?

Conclusions:

Did source water quality changes cause or contribute to your significant excursion(s)?

Yes ____ No __X__

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Report date: October 16th, 2004

B. Process Upset at Treatment Plant

- Was raw water stored for an unusually long time, providing additional contact time for DBP formation after prechlorination?

- Were there changes in coagulation practices?
  - Were there any changes or malfunctions of the coagulation process in the days leading to the excursion?
  - Were the coagulant dose and pH properly adjusted for incoming source water conditions?

- Were there changes in chlorination practices?
  - Were there any changes in chlorine dose at any location in the plant?
  - Were there changes in plant flow that may have resulted in longer than normal residence time at any location in the plant?
  - Did the pH change at the point of chlorine addition?

- Were there changes in settling practices?
  - Was there excess sludge build-up in the settling basin that may have carried over to the point of disinfectant addition?
  - Was there any disruption in the sludge blanket that may have resulted in carryover to the point of disinfection?

- Were there changes in filtration practices?
  - Have filter run times been changed to meet raw water quality changes?
  - Were there any spikes in individual filter effluent turbidity (which may indicate particulate or colloidal TOC breakthrough) in the days leading to the excursion?
  - Did chlorinated water sit in the filter for an extended period of time?
  - Were all filters run in a filter-to-waste mode during initial filter ripening?
  - Were any filters operated beyond their normal filter run time?
  - If GAC filters are used: Is it possible the adsorptive capacity of the GAC bed was reached before reactivation occurred?
  - If biological filtration is used: Were there any process upsets that may have resulted in breakthrough of TOC (particularly biodegradable TOC)?

- Were there changes in plant flow that may have resulted in an unusually high residence time in the clearwell on the days prior to the excursion?
  - For example, a temporary plant shutdown.

Continued on next page

B. Process Upset at Treatment Plant (Continued)

Conclusions:

Did a process upset in the treatment plant cause or contribute to your significant excursion(s)?

Yes X No ____

If yes, please explain:

The combination of two process changes at the Hardwood Plant is the most probable cause of the DBP excursion noted during the September 2004 sampling event. Specifically the two events were:

- Pre-oxidation of raw water with chlorine for taste and odor control following an algae bloom in Hardwood Lake. Chlorine addition to the raw water is not a routine practice.

- Ferric chloride was underfed for two days around the September 2004 sampling resulting in a decrease in TOC removal at the Hardwood Plant. The increased TOC concentration passing through the treatment process has probably lead to increased formation of TTHM and HAA5. The low ferric dose was the result of poor calibration of the standby pumps that were placed in service during the maintenance of the feed pumps that are normally used. It was noticed that pH of coagulation increased from the usual 5.5 to 6.2 range to 7.1 to 7.3.

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

C. Planned Change or Maintenance Activities for the Treatment Plant

- Was there a recent change (or addition) of pre-oxidant?
- Was there any maintenance in the basin that may have stirred sludge from the bottom of the basin and caused it to carry over to the point of disinfectant addition?
- Did you change the type or manufacturer of the coagulant?
- Were there any changes in disinfection practices in the days prior to the excursion?
  - For example, a switch from chloramines to free chlorine for burnout period.
  - Discontinuation of ozone which forms very little TTHM.
- Was a filter(s) taken off-line for an extended period of time that caused the other filters to operate near maximum design capacity and creating the conditions for possible breakthrough?
- Were any pumps shut down for maintenance, leading to changes in flow patterns or hydraulic surges?

Conclusions:

Did a planned maintenance or operational activity in the treatment plant cause or contribute to your significant excursion(s)?

Yes_____ No __X___

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

D. Planned Distribution System Operations or Maintenance Activities

- Was a tank drained for cleaning or other maintenance?
  - Was the tank drained to waste or to the distribution system?
  - Was a larger volume than normal drained to the distribution system?

- If booster disinfection is used, was the booster disinfectant dose higher than the normal booster disinfectant dose for that season?

- Were there any system maintenance activities in the days prior to DBP excursion? Including:
  - Repairing mains or installing new mains
  - Closure of valves to isolate sections of pipes

- Were the pipes flushed properly or were the appropriate valves re-opened after work was completed?

- Did any pump or pipeline maintenance occur that would have changed the flow pattern in the area the sample was drawn from?
  - Change in flow can cause water in stagnant areas to be drawn into another area.

- Did any pipeline replacement occur?
  - Disinfecting piping in contact with drinking water could result in a high concentration of chlorine entering the distribution system and thus increase DBPs.

Conclusions:

Did a planned distribution system maintenance or operational activity cause or contribute to your significant excursion(s)?

Yes_____ No __X___

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

E. Unplanned Distribution System Events

- Were there increases in demand that caused older water in storage tanks to be drawn into the system?
  - Were there any major fire events?
  - Did one or more storage tank have greater than average drawdown preceding the time of DBP peak excursion?

- Were there decreases in demand that resulted in longer than normal system residence times?
  - Were there any large customers off-line?

- Did any main breaks occur causing changes in flow patterns in the influence area of the sample location?

- If you collect water temperature inside storage tanks, was the temperature inside the tank higher than normal for the season?

- Were any storage tanks hydraulically locked out of the system for an extended period and then used preceding the time of DBP peak excursion?

- Did changes in overall water demand cause a change in water demand patterns in the vicinity of dead ends and/or stagnant zones in the system?

- Were there large variations in localized system pressures that were different from the normal pressure range that could have caused a change in water demand patterns in the vicinity of dead ends and/or stagnant zones in the system?

Conclusions:

Did an unplanned distribution system maintenance or operational activity cause or contribute to your significant excursion(s)?

Yes____ No __X__

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Report date: October 16th, 2004

F. If you were unable to identify the cause of your significant excursion(s) after reviewing Sections A through E, are you able to identify another potential cause of your increase in DBP concentrations? Explain.

Note: *If you are unable to determine the cause of your excursion you may wish to consider:*

- More frequent raw water temperature monitoring.
- More frequent raw water TOC monitoring.
- Increased disinfectant residual monitoring in the distribution system.
- Tracer studies to characterize distribution system water age.
- Development of a hydraulic model to characterize the distribution system.

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Supplemental Data Form for the Significant Excursion Evaluation Report

Report date: October 16th, 2004

Report prepared by: Ronald Doe, P.E.

System name: Elm City

1) Water quality data from significant excursion sampling period.

Location No.	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**
Location Name								
TTHM (ug/L)	***118***	***145***	***122***	82	68	70	58	78
HAA5 (ug/L)	***84***	***75***	65	58	47	53	30	50
Free Chlorine (mg/L)	0.6	0.8	0.2	NA	NA	1.1	NA	0.8
Total Chlorine (mg/L)	0.8	1.2	0.4	NA	NA	1.8	NA	1.2
pH	8.2	8.5	7.9	8.1	7.8	8.3	7.5	8.2

2) Supplemental data from each treatment facility:

Plant #1: Hardwood Plant
Raw Water Temperature: NA

Plant Effluent Water Temperature: 20 °C

Raw Water TOC: 2.2 mg/L (Avg. - 2.0mg/L)
Other Data:

Plant #2: Softwood Plant
Raw Water Temperature: NA

Plant Effluent Water Temperature: 20 °C

Raw Water TOC: 1.8 mg/L (Avg. - 2.0mg/L)
Other Data: Inf. turb. 25 ntu (Avg. - 20 ntu)

3) Historical TTHM and HAA5 data at significant excursion sampling locations.

TTHM Data (ug/L)

Monitoring Location	# 1	# 2	# 3	#
Date - 1999	61	78	45	
Date - 2000	55	59	56	
Date - 2001	70	69	41	
Date - 2002	64	81	73	
Date - 2003	66	54	53	
Avg. 99-03	63	68	54	

HAA5 Data (ug/L)

Monitoring Location	# 1	# 2	#	#
Date - 1999	32	56		
Date - 2000	29	47		
Date - 2001	48	23		
Date - 2002	36	34		
Date - 2003	41	45		
Avg. 99-03	37	45		

Attach additional sheets if necessary

Appendix D

Changes in Distribution System Operation

Significant Excursions Identified Using the “Maximum Concentration Approach”

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The first part of this appendix includes general system information and a summary of TTHM and HAA5 data that resulted in Elm City having to perform a significant excursion evaluation. This information is not required e as part of the documenntation of a significant excursion. Only the Significant Excursion Report is required to be completed by systems that experience a significant excursion.

This appendix is provided as an example of a system in which changes in distribution system operations led to a DBP Significant Excursion. Possible strategies to reduce excursions are presented in Chapter 4, but they are not to be included in the identification and documentation process. Appendices B, C, and E provide similar examples for systems in which changes in source water quality, changes in treatment plant operations, and multiple causes resulted in a significant excursion.

This example assumes the state has chosen to use 100 μg/L TTHM and 75 μg/L HAA5 as the trigger levels for determining that a significant excursion has occurred and that a significant excursion evaluation is required.

Background Information for this Example

System Description:

General system characteristics:

Service area: Elm City plus surrounding suburban areas
Production: Annual average daily demand 15 MGD

Source Water Information:

- Hardwood Lake (surface water)
  - pH: from 6.9 to 7.5
  - Alkalinity: from 82 to 98 mg/L as $CaCO_3$
  - TOC: from 2.1 to 4.0 mg/L as C
  - Bromide: from 0.04 to 0.1 mg/L
  - Turbidity: 1 to 100 ntu
- Softwood River (surface water)
  - pH: from 6.8 to 7.9
  - Alkalinity: from 77 to 94 mg/L as $CaCO_3$
  - TOC: from 1.6 to 9.4 mg/L as C
  - Bromide: from 0.03 to 0.1 mg/L
  - Turbidity: 2 to 115 ntu

Treatment Provided:

Hardwood, conventional (15 MGD design, 7.5 MGD average)
Softwood River, conventional with GAC (20 MGD design, 7.5 MGD average)
Primary and residual disinfection: Chlorine/chlorine at both plants

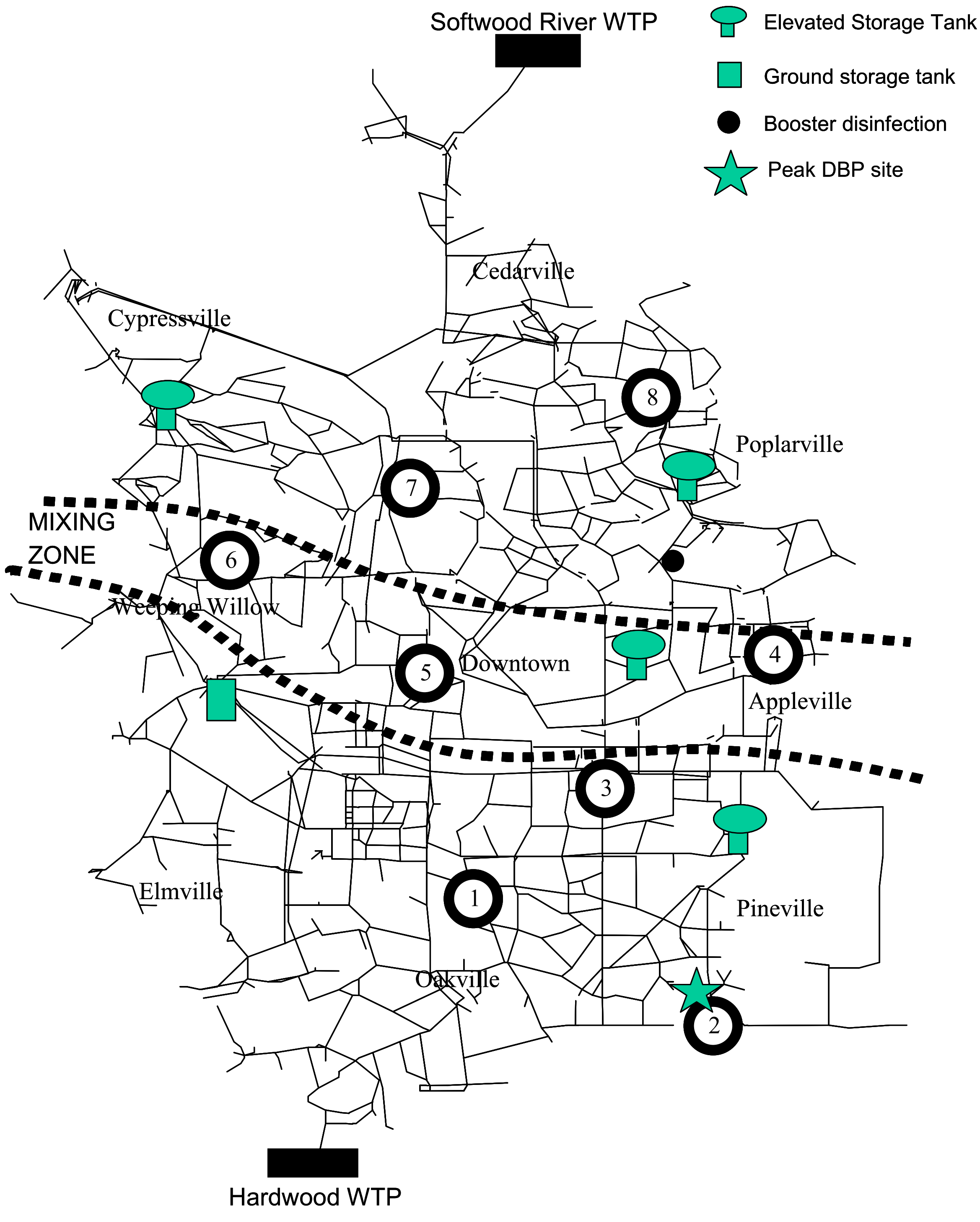
Summary of Stage 2 DBPR Monitoring Locations:

Table D.1 summarizes the Stage 2 DBPR monitoring locations used by Elm City. Sample locations are marked in the distribution system schematic presented in Figure D.1.

Table D.1 Stage 2 DBPR Monitoring Locations

Location	Description
Location #1	Hardwood Plant - average residence time
Location #2	Hardwood Plant - high TTHM
Location #3	Hardwood Plant - high HAA5
Location #4	Hardwood/Softwood Mix Zone - high TTHM
Location #5	Hardwood/Softwood Mix Zone - high TTHM
Location #6	Hardwood/Softwood Mix Zone - high TTHM
Location #7	Softwood Plant - average residence time
Location #8	Softwood Plant - high HAA5

Figure D.1 Schematic of Elm City Distribution System and Stage 2 DBPR Monitoring Locations



DBP Excursion Investigation:

During the last sampling period which took place in September 2004, Elm City experienced unusually high TTHM values (relative to the LRAA) at monitoring location #2. DBP data from the previous year and most recent sampling period (five quarters total) are presented in Table D.2.

Table D.2 TTHM and HAA5 Monitoring Data

Location	TTHM (ug/L)				HAA5 (ug/L)			
	Quarterly Pre-Sept 2004 Data[1]	LRAA Pre-Sept 2004	Sept 2004 Data	LRAA incl. Sept 2004	Quarterly Pre-Sept 2004 Data[1]	LRAA Pre-Sept 2004	Sept 2004 Data	LRAA incl. Sept 2004
#1	54, 67, 58, 75	65	72	68	52, 37, 30, 41	40	53	40
#2	49, 39, 50, 76	52	**<u>122</u>**	72	43, 39, 41, 45	42	49	44
#2	68, 68, 55, 69	63	69	65	38, 45, 28, 19	33	40	33
#3	66, 52, 71, 72	64	76	68	41, 46, 45, 39	43	58	47
#4	50, 55, 51, 61	55	82	60	42, 43, 38, 34	39	54	42
#5	34, 48, 55, 50	44	68	48	32, 43, 55, 38	42	37	43
#6	44, 62, 58, 60	49	70	63	45, 33, 41, 40	40	53	42
#7	40, 41, 37, 46	41	58	46	21, 38, 28, 19	27	29	29
#8	68, 68, 55, 69	63	69	65	38, 45, 28, 19	33	40	33

[1]Data for sampling conducted on September 2003, December 2003, March 2004 and June 2004. Data relevant to peak excursions are **<u>bold and underlined</u>**.

Unusually high TTHM concentrations were observed at location #2. The results are significantly higher than both the LRAA at those locations for the previous 12-month period and the historic TTHM and HAA5 values at those locations for the years 1999-2003 (see Significant Excursions Evaluation Report). Data for September 2004 meets the criteria of peak excursion. The city staff does not believe that treatment plant or source water quality changes caused the increase in the DBP level because such changes would likely impact all locations supplied by the treatment plant or source water, but only one location was affected by high DBP level. The city staff believes that distribution system operations in the vicinity of the location caused the increase in the DBP level.

Significant Excursion Evaluation Report

Page 1

Report date: October 16th, 2004

Report prepared by: Ronald Doe, P.E.

System name: Elm City

1) When was the significant excursion sample(s) collected? What were the TTHM and HAA5 concentrations?

Location No.	# 2	# ______	# ______	# ______
Location description	Hardwood Plant - high TTHM			
Sample collection date	Sept. 4, 2004			
Sample collection time	2 p.m.			
TTHM LRAA Concentration (ug/L)	72			
TTHM Concentration (ug/L)	122			
HAA5 LRAA Concentration (ug/L)				
HAA5 Concentration (ug/L)				

Note: Attach additional sheets if you observed more than four significant excursions during this round of sampling.

2) Where did the excursion(s) occur? Attach a schematic of your system, sketch your system in the space below, or have a schematic of your system available to review with your state at the time of your next sanitary survey. Indicate the location(s) of the significant excursion(s) on your schematic.

Location #2 – Represents high residence time of water leaving the Hardwood Plant. It is located in the Pineville neighborhood. An elevated storage tank also supplies water to this subdivision.

The location of these sample locations is illustrated in Figure D.1.

Significant Excursion Evaluation Report
Page 2

Report date: October 16th, 2004

3) Attach (or provide in the Supplemental Data Form) all available water quality data for the round of sampling in which the significant excursion occurred. At a minimum, include all TTHM and HAA5 results from the sampling period. You should also consider including pH, temperature, alkalinity, TOC, disinfectant residual, and any other data that you think would be useful.

   a) Were there any unusual circumstances associated with this round of sampling?

      Yes____ No__X__

      If yes, please explain.

   b) Were all analytical QA/QC measures met?

      Sample preservation Yes__X___ No_____

      Sample holding time Yes__X___ No_____

      Other ____________________

      ____

      ____

      If no, please explain.

4) Attach (or provide in the Supplemental Data Form) historical TTHM and HAA5 data for the location(s) at which the significant excursion(s) occurred. Provide at least three years of data, if available.

Significant Excursion Evaluation Report

Report date: October 16th, 2004

5) What caused your excursion(s) to occur?

Sections A through F starting on page 4 can help you determine the possible cause(s) of your excursion. Please note there may be more than one factor which resulted in your excursion.

Section A: Source water quality change
Section B: Process upset at treatment plant
Section C: Planned change or maintenance activities at plant
Section D: Planned distribution system operations or maintenance activities
Section E: Unplanned events in distribution system

If you already suspect a cause, go directly to that section. If you read Sections A through E and are unable to determine a cause of your excursion, then complete Section F.

Consecutive systems should also contact their wholesaler to identify the cause(s) of the significant excursion(s).

6) List steps taken or planned to reduce DBP peak levels.

Considering modifications to configuration of inflow piping at the Pineville tank to improve mixing.

Significant Excursion Evaluation Report

Page 4

Report date: October 16th, 2004

A. Source Water Quality Changes

- Did any of the events listed below take place before the DBP excursion to cause TOC levels to increase?
  - Heavy rain fall
  - Flooding
  - Spring snow-melt/runoff
  - Significant decrease in rainfall or source flow
  - Algae bloom
- Did any of the events listed below take place before the DBP excursion to cause bromide levels to increase?
  - Significant decrease in rainfall or source flow
  - Brackish or seawater intrusion
- Did pH and/or alkalinity significantly change?
- If two or more supplies are used, was a greater portion of water drawn from the one with higher TOC?
- Was raw water stored for an unusually long period of time resulting in a significant increase in water temperature?

Conclusions:

Did source water quality changes cause or contribute to your significant excursion(s)?

Yes ____ No __X____

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

B. Process Upset at Treatment Plant

- Was raw water stored for an unusually long time, providing additional contact time for DBP formation after prechlorination?

- Were there changes in coagulation practices?
  - Were there any changes or malfunctions of the coagulation process in the days leading to the excursion?
  - Were the coagulant dose and pH properly adjusted for incoming source water conditions?

- Were there changes in chlorination practices?
  - Were there any changes in chlorine dose at any location in the plant?
  - Were there changes in plant flow that may have resulted in longer than normal residence time at any location in the plant?
  - Did the pH change at the point of chlorine addition?

- Were there changes in settling practices?
  - Was there excess sludge build-up in the settling basin that may have carried over to the point of disinfectant addition?
  - Was there any disruption in the sludge blanket that may have resulted in carryover to the point of disinfection?

- Were there changes in filtration practices?
  - Have filter run times been changed to meet raw water quality changes?
  - Were there any spikes in individual filter effluent turbidity (which may indicate particulate or colloidal TOC breakthrough) in the days leading to the excursion?
  - Did chlorinated water sit in the filter for an extended period of time?
  - Were all filters run in a filter-to-waste mode during initial filter ripening?
  - Were any filters operated beyond their normal filter run time?
  - If GAC filters are used: Is it possible the adsorptive capacity of the GAC bed was reached before reactivation occurred?
  - If biological filtration is used: Were there any process upsets that may have resulted in breakthrough of TOC (particularly biodegradable TOC)?

- Were there changes in plant flow that may have resulted in an unusually high residence time in the clearwell on the days prior to the excursion?
  - For example, a temporary plant shutdown.

Continued on next page

Significant Excursion Evaluation Report
Page 6

Report date: October 16th, 2004

B. Process Upset at Treatment Plant (Continued)

Conclusions:

Did a process upset in the treatment plant cause or contribute to your significant excursion(s)?

Yes____ No __X__

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

C. Planned Change or Maintenance Activities for the Treatment Plant

- Was there a recent change (or addition) of pre-oxidant?

- Was there any maintenance in the basin that may have stirred sludge from the bottom of the basin and caused it to carry over to the point of disinfectant addition?

- Did you change the type or manufacturer of the coagulant?

- Were there any changes in disinfection practices in the days prior to the excursion?
  – For example, a switch from chloramines to free chlorine for burnout period.
  – Discontinuation of ozone which forms very little TTHM.

- Was a filter(s) taken off-line for an extended period of time that caused the other filters to operate near maximum design capacity and creating the conditions for possible breakthrough?

- Were any pumps shut down for maintenance, leading to changes in flow patterns or hydraulic surges?

Conclusions:

Did a planned maintenance or operational activity in the treatment plant cause or contribute to your significant excursion(s)?

Yes_____ No __X___

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

D. Planned Distribution System Operations or Maintenance Activities

- Was a tank drained for cleaning or other maintenance?
  - Was the tank drained to waste or to the distribution system?
  - Was a larger volume than normal drained to the distribution system?

- If booster disinfection is used, was the booster disinfectant dose higher than the normal booster disinfectant dose for that season?

- Were there any system maintenance activities in the days prior to DBP excursion? Including:
  - Repairing mains or installing new mains
  - Closure of valves to isolate sections of pipes

- Were the pipes flushed properly or were the appropriate valves re-opened after work was completed?

- Did any pump or pipeline maintenance occur that would have changed the flow pattern in the area the sample was drawn from?
  - Change in flow can cause water in stagnant areas to be drawn into another area.

- Did any pipeline replacement occur?
  - Disinfecting piping in contact with drinking water could result in a high concentration of chlorine entering the distribution system and thus increase DBPs.

Conclusions:

Did a planned distribution system maintenance or operational activity cause or contribute to your significant excursion(s)?

Yes__X___ No _____

If yes, please explain:

Refer to the explanation following Section E.

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

E. Unplanned Distribution System Events

- Were there increases in demand that caused older water in storage tanks to be drawn into the system?
  - Were there any major fire events?
  - Did one or more storage tank have greater than average drawdown preceding the time of DBP peak excursion?

- Were there decreases in demand that resulted in longer than normal system residence times?
  - Were there any large customers off-line?

- Did any main breaks occur causing changes in flow patterns in the influence area of the sample location?

- If you collect water temperature inside storage tanks, was the temperature inside the tank higher than normal for the season?

- Were any storage tanks hydraulically locked out of the system for an extended period and then used preceding the time of DBP peak excursion?

- Did changes in overall water demand cause a change in water demand patterns in the vicinity of dead ends and/or stagnant zones in the system?

- Were there large variations in localized system pressures that were different from the normal pressure range that could have caused a change in water demand patterns in the vicinity of dead ends and/or stagnant zones in the system?

Conclusions:

Did an unplanned distribution system maintenance or operational activity cause or contribute to your significant excursion(s)?

Yes__X__ No _____

If yes, please explain:

The city staff believes distribution system operations caused the peak THM excursion. Therefore, the likelihood that distribution issues contributed to the peak THM excursion has been explored first. To determine the cause of the THM peak excursion, the city staff reviewed the following information for a period of two weeks prior to the occurrence of peak THM excursion:

- System maintenance activities
- Main breaks
- System pressure fluctuations
- Overall system demand
- Water level in storage tanks
- Boost disinfection operation

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

System maintenance activities:
Installation of a new 12-inch main for a new development in Elmville subdivision was completed. The city staff reviewed the main disinfection logbook which indicated that the new main was flushed properly, and chlorine residual in the pipe was 1 mg/L before it was connected to the rest of the water system. Three valves were closed to isolate sections of pipes from the rest of the water system. during installation of the new main. These valves were checked to make sure that they were all opened after installation of the new main was completed. One valve was found to be inadvertently left in the closed position. However, the closure of this valve did not affect the water quality in Pineville subdivision where the peak THM concentration occurred. The city's hydraulic model indicated that water does not flow from Elmville to Pineville and closing the valve in the pipe in Elmville does not alter the water flow patters in Pineville.

Main breaks:
A road repair worker in Pineville subdivision damaged a 12-inch water main that runs along that road. The broken section of the water main was isolated and shut off within two hours. However, it is anticipated that there was significant loss of water during those two hours. Hydraulic analyses using the city's hydraulic model have indicated that the piping network in Pineville does not have any stagnant zones with high residence time. Also, using the city's hydraulic model to simulate the main break by creating artificial demand at the location of the main break indicated that the influence of the main break did not draw water from any stagnant zones towards the sample location where peak THM excursion occurred.

System pressure fluctuations:
The distribution system pressure in the Pineville subdivision was generally within the normal range expected for the month of September, approximately 52-65 psi. However, the pressure was about 10 psi lower at the location of the main break for about two hours. As soon as the damaged section of the main was isolated, the pressure at that location returned to the normal pressure range generally expected for the month of September. The piping network in Pineville does not have any stagnant zones. There may be stagnant zones outside the Pineville subdivision, but the lower pressure in the vicinity of the peak THM occurrence did not impact water flow patterns outside the Pineville subdivision, as verified by the city's hydraulic model.

Overall system demand:
The total hourly distribution system demand was checked using treatment plant production figures and tank level data. The hourly total system demand during September 2004 ranged between 14-17 mgd, which was also the general range for the system demand during the month of September for 1999-2003. An unusual increase or decrease in the total system demand was not observed two weeks prior to the peak THM occurrence. The loss of water due to the main break did not cause a significant change in the overall system demand. Therefore, there was not any unusual shift in the water demand patterns and water flow patterns in the vicinity of stagnant zones and thus did not contribute to the peak THM occurrence.

Water level in storage tanks:
The hourly water level for all the tank in Elm City was plotted using the SCADA system data. The water levels fluctuated within the normal range for all the tanks except for the elevated tank located in Pineville. The water level in the Pineville tank generally fluctuates approximately 20 feet to 35 feet above the bottom of the tank. The water level in this tank dropped to about 12 feet above the bottom of the tank at the time of the main break and then rose to normal levels once the broken section of the main was isolated. The increased water demand and pressure drop at the location of the main break was responsible for the unusual drop in the water level of the Pineville tank. The proximity of Sample Location 2 to the main break also decreased the pressure at the sampling location, this allowing the water from the top portion of the tank to reach that location during the main break. The SCADA data indicated that the average inflow rate into the tank is 1000 gpm and the inlet diameter is 36 inches. This inflow rate and inlet diameter may not provide adequate momentum to mix the water near the top portion of the tank where the water came from during the main break. Therefore, the water age in the top portion of the tank was higher and may have caused the peak DBP level at Sample Site 2.

Booster disinfection operation:

There is a booster disinfection station located in the Polarville subdivision. The disinfectant residual leaving this booster station was within the normal range of 1-2 mg/L. Pineville subdivision receives all the water either from the treatment plant directly or from the Pineville tank. It does not receive any portion of its water from the booster station. Thus, the disinfectant residuals at the booster station did not contribute to peak THM occurrence at Location 2.

Significant Excursion Evaluation Report
Page 10

Report date: October 16th, 2004

F. If you were unable to identify the cause of your significant excursion(s) after reviewing Sections A through E, are you able to identify another potential cause of your increase in DBP concentrations? Explain.

Note: *If you are unable to determine the cause of your excursion you may wish to consider:*

- More frequent raw water temperature monitoring.
- More frequent raw water TOC monitoring.
- Increased disinfectant residual monitoring in the distribution system.
- Tracer studies to characterize distribution system water age.
- Development of a hydraulic model to characterize the distribution system.

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Supplemental Data Form for the Significant Excursion Evaluation Report	Report date: October 16th, 2004 Report prepared by: Ronald Doe, P.E. System name: Elm City

1) Water quality data from significant excursion sampling period.

Location No.	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**
Location Name								
TTHM (ug/L)	72	***122***	82	68	68	70	58	69
HAA5 (ug/L)	53	38	58	54	37	53	29	40
Free Chlorine (mg/L)	1.5	0.1	NA	0.5	0.8	1.1	NA	0.9
Total Chlorine (mg/L)	1.7	0.2	NA	0.7	1.1	1.5	NA	1.2
pH	7.9	8.0	8.3	8.1	7.8	8.3	7.5	8.2

2) Supplemental data from each treatment facility:

Plant #1: Hardwood Plant
Raw Water Temperature: NA
Plant Effluent Water Temperature: 20 °C
Raw Water TOC: 2.2 mg/L (Avg. - 2.0mg/L)

Other Data: ____________

Plant #2: Softwood Plant
Raw Water Temperature: NA
Plant Effluent Water Temperature: 20 °C
Raw Water TOC: 1.8 mg/L (Avg. - 2.0mg/L)

Other Data: Inf. turb.: 25 ntu (Avg - 20 ntu)

3) Historical TTHM and HAA5 data at significant excursion sampling locations.

TTHM Data (ug/L)

Monitoring Location # 2 #____ #____ #____ #____

Date - 1998	61
Date - 1999	55
Date - 2000	70
Date - 2001	64
Date - 2002	49
Avg. 98-02	60

HAA5 Data (ug/L)

Monitoring Location # 2 #____ #____

Date - 1998	32
Date - 1999	29
Date - 2000	48
Date - 2001	36
Date - 2002	43
Avg. 98-02	49

Attach additional sheets if necessary

Appendix E

Changes in Treatment Plant and Distribution System Operation

Significant Excursions Identified Using the "Maximum Concentration Approach"

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The first part of this appendix includes general system information and a summary of TTHM and HAA5 data that resulted in Elm City having to perform a significant excursion evaluation. This information is not required when documenting a significant excursion. Only the Significant Excursion Report is required to be completed by systems that experience a significant excursion.

This appendix is provided as an example of a system in which changes in both treatment plant and distribution system operations led to a DBP Significant Excursion. Possible strategies to reduce excursions are presented in Chapter 4, but they are not to be included in the identification and documentation process. Appendices B through D provide similar examples for systems in which one primary change either in source water quality, treatment plant operations, or distribution system operations resulted in a significant excursion.

This example assumes the state has chosen to use 100 μg/L TTHM and 75 μg/L HAA5 as the trigger levels for determining that a significant excursion has occurred and that a significant excursion evaluation is required.

Background Information for this Example

System Description:

General system characteristics:

Service area: Elm City plus surrounding suburban areas
Production: Annual average daily demand 15 MGD

Source Water Information:

- Hardwood Lake (surface water)
  - pH: from 6.9 to 7.5
  - Alkalinity: from 82 to 98 mg/L as $CaCO_3$
  - TOC: from 2.1 to 4.0 mg/L as C
  - Bromide: from 0.04 to 0.1 mg/L
  - Turbidity: 1 to 100 ntu
- Softwood River (surface water)
  - pH: from 6.8 to 7.9
  - Alkalinity: from 77 to 94 mg/L as $CaCO_3$
  - TOC: from 1.6 to 9.4 mg/L as C
  - Bromide: from 0.03 to 0.1 mg/L
  - Turbidity: 2 to 115 ntu

Treatment Provided:

Hardwood, conventional (15 MGD design, 7.5 MGD average)
Softwood River, conventional with GAC (20 MGD design, 7.5 MGD average)
Primary and residual disinfection: Chlorine/chlorine at both plants

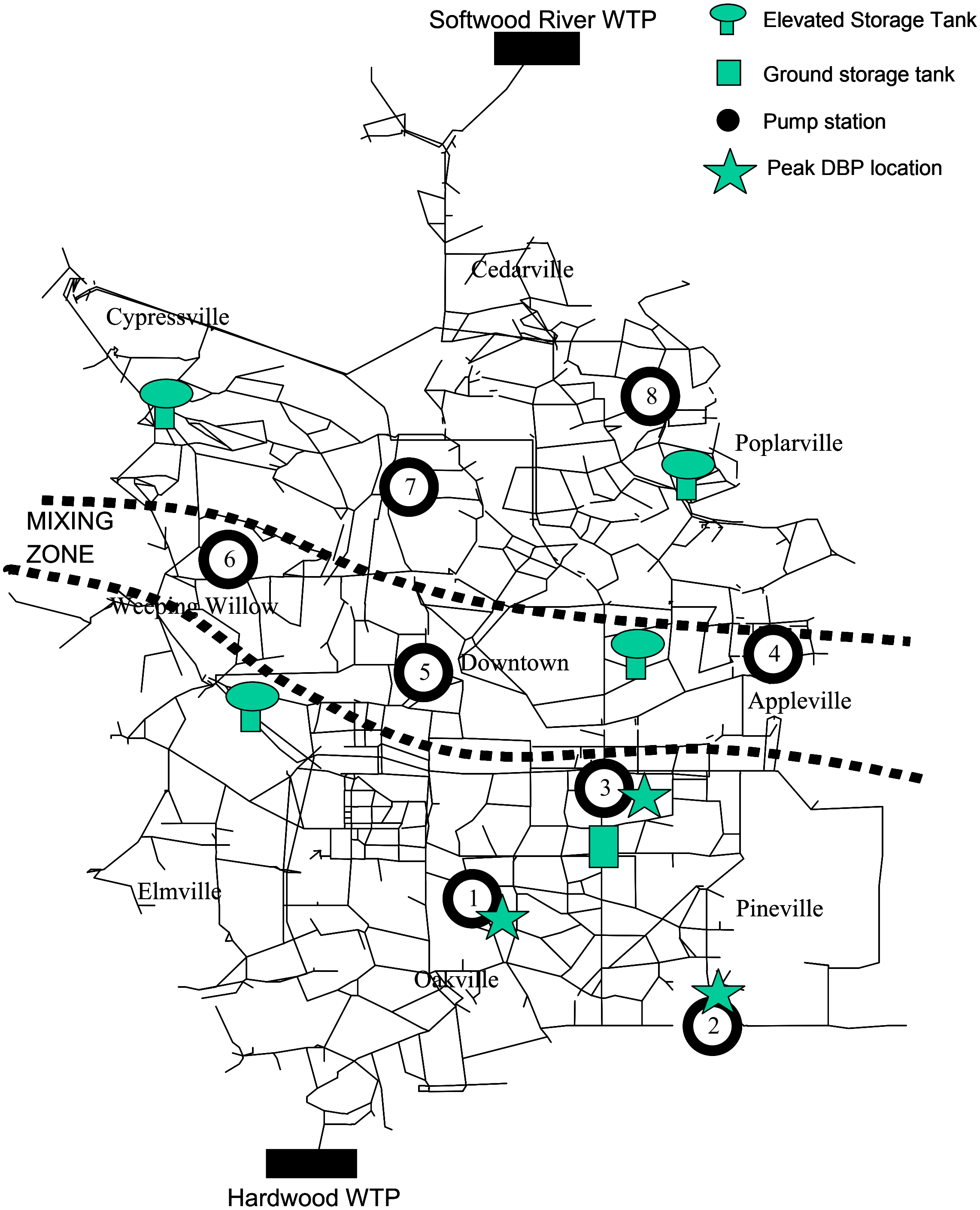
Summary of Stage 2 DBPR Monitoring Locations:

Table E.1 summarizes the Stage 2 DBPR monitoring locations used by Elm City. Sample locations are marked in the distribution system schematic presented in Figure E.1.

Table E.1 Stage 2 DBPR Monitoring Locations

Location	Description
Location #1	Hardwood Plant - average residence time
Location #2	Hardwood Plant - high TTHM
Location #3	Hardwood Plant - high HAA5
Location #4	Hardwood/Softwood Mix Zone - high TTHM
Location #5	Hardwood/Softwood Mix Zone - high TTHM
Location #6	Hardwood/Softwood Mix Zone - high TTHM
Location #7	Softwood Plant - average residence time
Location #8	Softwood Plant - high HAA5

Figure E.1 Schematic of Elm City Distribution System and Stage 2 DBPR Monitoring Locations



DBP Excursion Investigation:

During the last sampling period which took place in September 2004, Elm City experienced unusually high TTHM values (relative to the LRAA) at three monitoring locations (#1, #2, #3). Similarly, unusually high HAA5 values were detected at two monitoring locations (#1 and #2). DBP data from the previous year and most recent sampling period (five quarters total) are presented in Table E.2.

Table E.2 TTHM and HAA5 Monitoring Data

Location	TTHM (ug/L)				HAA5 (ug/L)			
	Quarterly Pre-Sept. 2004 Data[1]	LRAA Pre-Sept. 2004 Avg.	Sept. 2004 Data	LRAA Sept. 2004 Avg.	Quarterly Pre-Sept. 2004 Data[1]	LRAA Pre-Sept. 2004 Avg.	Sept. 2004 Data	LRAA Sept. 2004 Avg.
#1	54, 67, 58, 75	65	**<u>118</u>**	74	52, 37, 30, 41	40	**<u>84</u>**	48
#2	68, 68, 55, 69	63	**<u>145</u>**	77	38, 45, 28, 19	33	**<u>75</u>**	42
#3	66, 52, 71, 72	64	**<u>122</u>**	74	41, 46, 45, 39	43	58	47
#4	50, 55, 51, 61	55	82	60	42, 43, 38, 34	39	54	42
#5	34, 48, 55, 50	44	68	48	32, 43, 55, 38	42	37	43
#6	44, 62, 58, 60	49	70	53	45, 33, 41, 40	40	53	42
#7	40, 41, 37, 46	41	58	46	21, 38, 28, 19	27	29	29
#8	49, 39, 50, 76	52	78	56	43, 39, 41, 45	42	49	44

[1]Data for sampling conducted on September 2003, December 2003, March 2004 and June 2004. Data relevant to peak excursions are **<u>bold and underlined</u>**.

Unusually high TTHM samples were collected at locations #1, #2, and #3, and unusually high HAA5 samples were collected at locations #1 and #2. The results are significantly higher than both the LRAA at those locations for the previous 12-month period and the historic TTHM and HAA5 values at those locations for the years 1998-2002 (see Significant Excursions Evaluation Report). Significant excursions were identified when DBP levels exceeded 100 μg/L TTHM or 75 μg/L HAA5. All of the monitoring locations affected by high DBP are located in the area served by the Hardwood plant. The city staff has reason to believe that a process change that occurred during treatment operations at the Hardwood plant caused this increase in DBP levels.

Significant Excursion Evaluation Report

Page 1

Report date: October 16, 2004

Report prepared by: Ronald Doe, P.E.

System name: Elm City

1) When was the significant excursion sample(s) collected? What were the TTHM and HAA5 concentrations?

Location No.	# 1	# 2	# 3	# ______
Location description	Hardwood Plant - average residence time	Hardwood Plant - high TTHM	Hardwood Plant - high HAA5	
Sample collection date	Sept. 4, 2004	Sept. 4, 2004	Sept. 4, 2004	
Sample collection time	3 p.m.	2 p.m.	12 noon	
TTHM LRAA Concentration (ug/L)	74	77	74	
TTHM Concentration (ug/L)	118	145	122	
HAA5 LRAA Concentration (ug/L)	48	42		
HAA5 Concentration (ug/L)	84	75		

Note: Attach additional sheets if you observed more than four significant excursions during this round of sampling.

2) Where did the excursion(s) occur? Attach a schematic of your system, sketch your system in the space below, or have a schematic of your system available to review with your state at the time of your next sanitary survey. Indicate the location(s) of the significant excursion(s) on your schematic.

Location #1 – Represents the average residence time of water leaving the Hardwood Plant. It is located in the Oakville neighborhood. There are no storage facilities between the treatment plant and this location

Location #2 – Sample tap is a hose bib at a building located in Pineville in a zone of the distribution system with water age greater than average. Water in this area is from the Hardwood Plant.

Location #3– This location is located in the downtown area. Water is primarily from Hardwood Plant. A ground storage tank is near this location.

Report date: October 16, 2004

3) Attach (or provide in the Supplemental Data Form) all available water quality data for the round of sampling in which the significant excursion occurred. At a minimum, include all TTHM and HAA5 results from the sampling period. You should also consider including pH, temperature, alkalinity, TOC, disinfectant residual, and any other data that you think would be useful.

   a) Were there any unusual circumstances associated with this round of sampling?

      Yes____ No__X__

      If yes, please explain.

   b) Were all analytical QA/QC measures met?

      Sample preservation Yes__X__ No_____

      Sample holding time Yes__X__ No_____

      Other ____________________

      ____

      ____

      If no, please explain.

4) Attach (or provide in the Supplemental Data Form) historical TTHM and HAA5 data for the location(s) at which the significant excursion(s) occurred. Provide at least three years of data, if available.

Significant Excursion Evaluation Report

Page 3

Report date: October 16, 2004

5) What caused your excursion(s) to occur?

Sections A through F starting on page 4 can help you determine the possible cause(s) of your excursion. Please note there may be more than one factor which resulted in your excursion.

Section A: Source water quality change
Section B: Process upset at treatment plant
Section C: Planned change or maintenance activities at plant
Section D: Planned distribution system operations or maintenance activities
Section E: Unplanned events in distribution system

If you already suspect a cause, go directly to that section. If you read Sections A through E and are unable to determine a cause of your excursion, then complete Section F.

Consecutive systems should also contact their wholesaler to identify the cause(s) of the significant excursion(s).

6) List steps taken or planned to reduce DBP peak levels.

Considering modifications to configuration of inflow piping at the Pineville tank to improve mixing.

Considering improvements to coagulant process monitoring (daily verification of coagulant dose delivered with pump catch, streaming current monitoring) to minimize possible process upsets.

Report date: October 16, 2004

A. Source Water Quality Changes

- Did any of the events listed below take place before the DBP excursion to cause TOC levels to increase?
  - Heavy rain fall
  - Flooding
  - Spring snow-melt/runoff
  - Significant decrease in rainfall or source flow
  - Algae bloom

- Did any of the events listed below take place before the DBP excursion to cause bromide levels to increase?
  - Significant decrease in rainfall or source flow
  - Brackish or seawater intrusion

- Did pH and/or alkalinity significantly change?

- If two or more supplies are used, was a greater portion of water drawn from the one with higher TOC?

- Was raw water stored for an unusually long period of time resulting in a significant increase in water temperature?

Conclusions:

Did source water quality changes cause or contribute to your significant excursion(s)?

Yes ____ No __X___

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

B. Process Upset at Treatment Plant

- Was raw water stored for an unusually long time, providing additional contact time for DBP formation after prechlorination?

- Were there changes in coagulation practices?
  - Were there any changes or malfunctions of the coagulation process in the days leading to the excursion?
  - Were the coagulant dose and pH properly adjusted for incoming source water conditions?

- Were there changes in chlorination practices?
  - Were there any changes in chlorine dose at any location in the plant?
  - Were there changes in plant flow that may have resulted in longer than normal residence time at any location in the plant?
  - Did the pH change at the point of chlorine addition?

- Were there changes in settling practices?
  - Was there excess sludge build-up in the settling basin that may have carried over to the point of disinfectant addition?
  - Was there any disruption in the sludge blanket that may have resulted in carryover to the point of disinfection?

- Were there changes in filtration practices?
  - Have filter run times been changed to meet raw water quality changes?
  - Were there any spikes in individual filter effluent turbidity (which may indicate particulate or colloidal TOC breakthrough) in the days leading to the excursion?
  - Did chlorinated water sit in the filter for an extended period of time?
  - Were all filters run in a filter-to-waste mode during initial filter ripening?
  - Were any filters operated beyond their normal filter run time?
  - If GAC filters are used: Is it possible the adsorptive capacity of the GAC bed was reached before reactivation occurred?
  - If biological filtration is used: Were there any process upsets that may have resulted in breakthrough of TOC (particularly biodegradable TOC)?

- Were there changes in plant flow that may have resulted in an unusually high residence time in the clearwell on the days prior to the excursion?
  - For example, a temporary plant shutdown.

Continued on next page

Report date: October 16, 2004

B. Process Upset at Treatment Plant (Continued)

Conclusions:

Did a process upset in the treatment plant cause or contribute to your significant excursion(s)?

Yes__X__ No _____

If yes, please explain:

Ferric chloride was underfed for two days prior to the September 2004 sampling event resulting in lower TOC removal at the Hardwood plant. The increased TOC concentration passing through the treatment process contributed to increased formation of TTHM and HAA5 at Locations 1, 2, and 3 as these locations are supplied by the Hardwood treatment plant. The low ferric dose was the result of poor calibration of the standby feed pumps that were placed in service during the maintenance of the duty feed pumps. The pH of coagulation increased from the usual 5.5 to 6.2 range to 7.1 to 7.3 during the low coagulant dose.

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

C. Planned Change or Maintenance Activities for the Treatment Plant

- Was there a recent change (or addition) of pre-oxidant?
- Was there any maintenance in the basin that may have stirred sludge from the bottom of the basin and caused it to carry over to the point of disinfectant addition?
- Did you change the type or manufacturer of the coagulant?
- Were there any changes in disinfection practices in the days prior to the excursion?
  - For example, a switch from chloramines to free chlorine for burnout period.
  - Discontinuation of ozone which forms very little TTHM.
- Was a filter(s) taken off-line for an extended period of time that caused the other filters to operate near maximum design capacity and creating the conditions for possible breakthrough?
- Were any pumps shut down for maintenance, leading to changes in flow patterns or hydraulic surges?

Conclusions:

Did a planned maintenance or operational activity in the treatment plant cause or contribute to your significant excursion(s)?

Yes_____ No __X___

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

D. Planned Distribution System Operations or Maintenance Activities

- Was a tank drained for cleaning or other maintenance?
  - Was the tank drained to waste or to the distribution system?
  - Was a larger volume than normal drained to the distribution system?

- If booster disinfection is used, was the booster disinfectant dose higher than the normal booster disinfectant dose for that season?

- Were there any system maintenance activities in the days prior to DBP excursion? Including:
  - Repairing mains or installing new mains
  - Closure of valves to isolate sections of pipes

- Were the pipes flushed properly or were the appropriate valves re-opened after work was completed?

- Did any pump or pipeline maintenance occur that would have changed the flow pattern in the area the sample was drawn from?
  - Change in flow can cause water in stagnant areas to be drawn into another area.

- Did any pipeline replacement occur?
  - Disinfecting piping in contact with drinking water could result in a high concentration of chlorine entering the distribution system and thus increase DBPs.

Conclusions:

Did a planned distribution system maintenance or operational activity cause or contribute to your significant excursion(s)?

Yes_X___ No _____

If yes, please explain:

One area of the Pineville subdivision was flushed in response to customer complaints about water quality. The flushing activity created additional water demand in that area and reduced the pressure in the vicinity of the fire hydrants that were flushed. The low pressure altered water flow patterns and caused more than normal drawdown from one of the storage tanks. Simulation of the flushing activities using the city's hydraulic model indicated that a change in water flow pattern caused water from one of the stagnant zones in Oakwood subdivison to flow to the flushed areas. As the water flowed towards the flushed areas, it flowed through the vicinity of Location 3 bringing old water to this location.

An overview of the tank level data from SCADA indicated that the water level in Pineville tank generally drops to about 10 feet below the maximum tank water level of 35 feet. However, at the time of the flushing activities, the water level in this tank dropped 25 feet below the maximum tank water level. This unusual drop in water level caused the relatively unmixed water with high age to be drawn into the distribution system and reach Location 2 which is located close to the tank.

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Report date: October 16, 2004

E. Unplanned Distribution System Events

- Were there increases in demand that caused older water in storage tanks to be drawn into the system?
  – Were there any major fire events?
  – Did one or more storage tank have greater than average drawdown preceding the time of DBP peak excursion?

- Were there decreases in demand that resulted in longer than normal system residence times?
  – Were there any large customers off-line?

- Did any main breaks occur causing changes in flow patterns in the influence area of the sample location?

- If you collect water temperature inside storage tanks, was the temperature inside the tank higher than normal for the season?

- Were any storage tanks hydraulically locked out of the system for an extended period and then used preceding the time of DBP peak excursion?

- Did changes in overall water demand cause a change in water demand patterns in the vicinity of dead ends and/or stagnant zones in the system?

- Were there large variations in localized system pressures that were different from the normal pressure range that could have caused a change in water demand patterns in the vicinity of dead ends and/or stagnant zones in the system?

Conclusions:

Did an unplanned distribution system maintenance or operational activity cause or contribute to your significant excursion(s)?

Yes____ No X

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Significant Excursion Evaluation Report

Report date: October 16, 2004

F. If you were unable to identify the cause of your significant excursion(s) after reviewing Sections A through E, are you able to identify another potential cause of your increase in DBP concentrations? Explain.

Note: *If you are unable to determine the cause of your excursion you may wish to consider:*

- More frequent raw water temperature monitoring.
- More frequent raw water TOC monitoring.
- Increased disinfectant residual monitoring in the distribution system.
- Tracer studies to characterize distribution system water age.
- Development of a hydraulic model to characterize the distribution system.

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Supplemental Data Form for the Significant Excursion Evaluation Report

Report date: October 16, 2004

Report prepared by: Ronald Doe, P.E.

System name: Elm City

1) Water quality data from significant excursion sampling period.

Location No.	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**
Location Name								
TTHM (ug/L)	***118***	***145***	***122***	82	68	70	58	78
HAA5 (ug/L)	***84***	***75***	58	54	37	53	29	49
Free Chlorine (mg/L)	1.5	0.1	NA	0.5	0.8	1.1	NA	0.9
Total Chlorine (mg/L)	1.7	0.2	NA	0.7	1.1	1.5	NA	1.2
pH	7.9	8.0	8.3	8.1	7.8	8.3	7.5	8.2

2) Supplemental data from each treatment facility:

Plant #1: Hardwood plant
Raw Water Temperature: NA

Plant Effluent Water Temperature: 20 °C
Raw Water TOC: 3.2 mg/L (ave = 2.0)

Other Data:

Plant #2: Softwood plant
Raw Water Temperature: NA

Plant Effluent Water Temperature: 20 °C
Raw Water TOC: 1.8 mg/L (ave = 2.0)

Other Data: Plant influent turbidity = 25 ntu
Average = 20 ntu

3) Historical TTHM and HAA5 data at significant excursion sampling locations.

TTHM Data (ug/L)

Monitoring Location	# 1	# 2	# 3	#
Date 1998	61	78	45	
Date 1999	55	59	56	
Date 2000	70	69	41	
Date 2001	64	81	73	
Date 2002	66	54	53	
Avg.	63	68	54	

HAA5 Data (ug/L)

Monitoring Location	# 1	# 2	#	#
Date 1998	32	56		
Date 1999	29	47		
Date 2000	48	23		
Date 2001	36	34		
Date 2002	43	45		
Avg.	38	45		

Attach additional sheets if necessary

Appendix F

Changes in Source Water Quality

Significant Excursions Identified Using the “Difference Approach”

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The first part of this appendix includes general system information and a summary of TTHM and HAA5 data that resulted in Elm City having to perform a significant excursion evaluation. This information is not required as part of the documentation of a significant excursion. Only the Significant Excursion Report is required to be completed by systems that experience a significant excursion.

This appendix is provided as an example of a system in which changes in source water quality led to a DBP Significant Excursion. Possible strategies to reduce excursions are presented in Chapter 4, but they are not to be included in the identification and documentation process. Appendices C through E provide similar examples for systems in which changes in treatment plant operations, changes in distribution system, and multiple causes resulted in a significant excursion.

This example assumes the state has chosen to use the "difference approach" (see Chapter 1.1) for determining that a significant excursion has occurred and that a significant excursion evaluation is required.

Background Information for this Example

System Description:

General system characteristics:
- Service area: Elm City plus surrounding suburban areas
- Production: Annual average daily demand 15 MGD

Source Water Information:
- Hardwood Lake (surface water)
  - pH: from 6.9 to 7.5
  - Alkalinity: from 82 to 98 mg/L as $CaCO_3$
  - TOC: from 2.1 to 4.0 mg/L as C
  - Bromide: from 0.04 to 0.1 mg/L
  - Turbidity: 1 to 100 ntu
- Softwood River (surface water)
  - pH: from 6.8 to 7.9
  - Alkalinity: from 77 to 94 mg/L as $CaCO_3$
  - TOC: from 1.6 to 9.4 mg/L as C
  - Bromide: from 0.03 to 0.1 mg/L
  - Turbidity: 2 to 115 ntu

Treatment Provided:

Hardwood, conventional (15 MGD design, 7.5 MGD average)
Softwood River, conventional with GAC (20 MGD design, 7.5 MGD average)
Primary and residual disinfection: Chlorine/chlorine at both plants

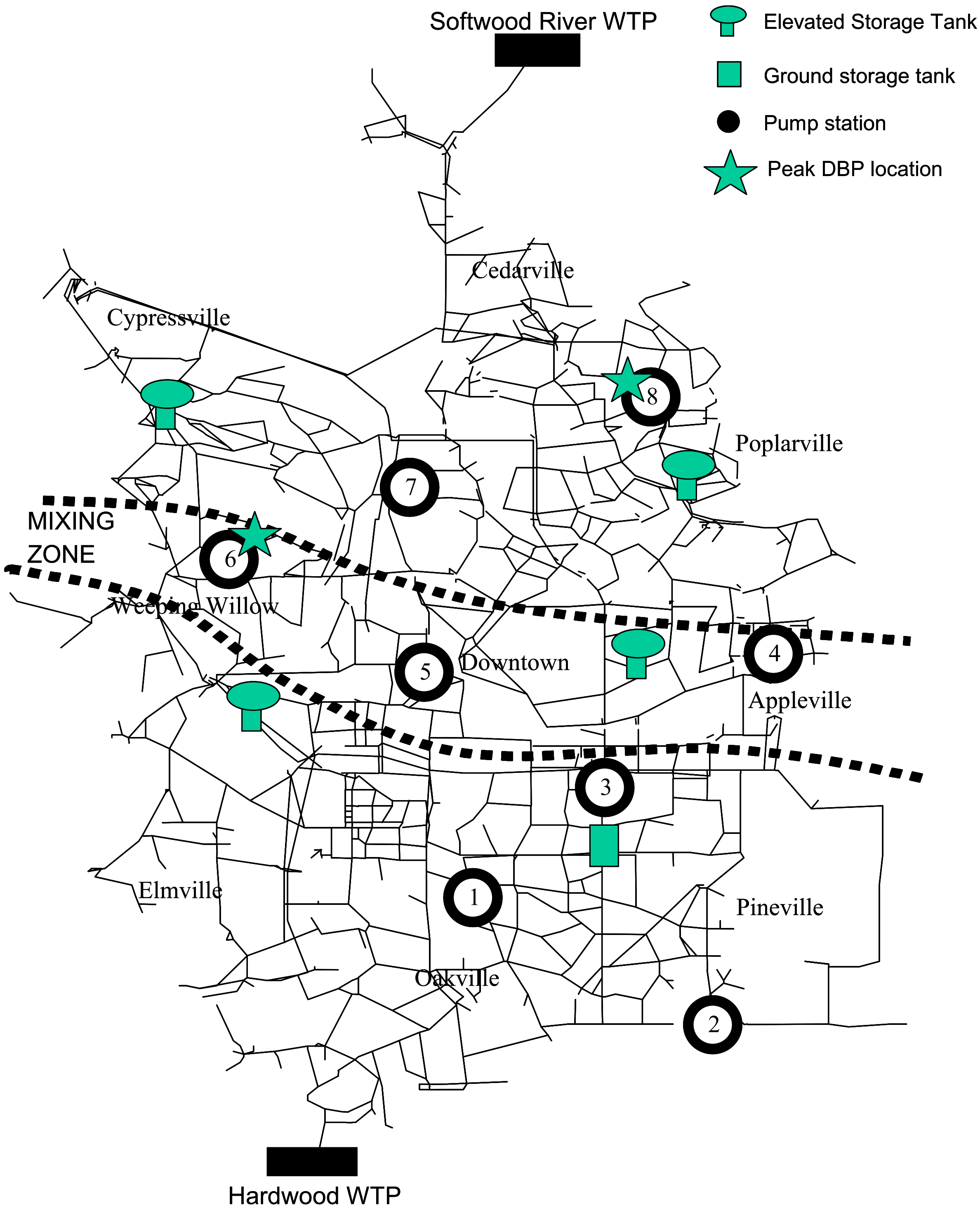
Summary of Stage 2 DBPR Monitoring Locations:

Table F.1 summarizes the Stage 2 DBPR monitoring locations used by Elm City. Sample locations are marked in the distribution system schematic presented in Figure F.1.

Table F.1 Stage 2 DBPR Monitoring Locations

Location	Description
Location #1	Hardwood Plant - average residence time
Location #2	Hardwood Plant - high TTHM
Location #3	Hardwood Plant - high HAA5
Location #4	Hardwood/Softwood Mix Zone - high TTHM
Location #5	Hardwood/Softwood Mix Zone - high TTHM
Location #6	Hardwood/Softwood Mix Zone - high TTHM
Location #7	Softwood Plant - average residence time
Location #8	Softwood Plant - high HAA5

Figure F.1 Schematic of Elm City Distribution System and Stage 2 DBPR Monitoring Locations



DBP Excursion Investigation:

During the last sampling period which took place in September 2004, Elm City experienced unusually high TTHM and HAA5 levels (relative to the LRAA). DBP data from the previous year and most recent sampling period (five quarters total) are presented in Table F.2.

Table F.2 TTHM and HAA5 Monitoring Data

Location	TTHM (ug/L)				HAA5 (ug/L)			
	Quarterly Pre-Sept. 2004 Data[1]	LRAA Pre-Sept. 2004 Avg.	Sept. 2004 Data	LRAA Sept. 2004 Avg.	Quarterly Pre-Sept. 2004 Data[1]	LRAA Pre-Sept. 2004 Avg.	Sept. 2004 Data	LRAA Sept. 2004 Avg.
#1	54, 67, 58, 75	65	63	67	52, 37, 30, 41	40	52	40
#2	68, 68, 55, 69	63	72	64	38, 45, 28, 19	33	39	33
#3	66, 52, 71, 72	64	81	68	41, 46, 45, 39	43	51	46
#4	50, 55, 51, 61	55	78	62	42, 43, 38, 34	39	66	45
#5	34, 48, 55, 50	44	**79**	55	32, 43, 55, 38	42	58	49
#6	44, 62, 58, 60	49	**121**	66	45, 33, 41, 40	40	**72**	47
#7	40, 41, 37, 46	41	**77**	50	31, 38, 28, 19	27	**59**	37
#8	49, 39, 50, 76	52	**146**	76	43, 39, 41, 45	42	**98**	56

[1]Data for sampling conducted on September 2003, December 2003, March 2004 and June 2004. Data relevant to peak excursions are **bold and underlined**.

Unusually high TTHM samples were collected at locations #5, #6, #7 and #8, and unusually high HAA5 samples were collected at locations #6, #7 and #8. The results are significantly higher than both the LRAA at those locations for the previous 12-month period and the historic TTHM and HAA5 values at those locations for the years 1999-2003 (see Significant Excursions Evaluation Report). Significant excursions (see Chapter 1.1) were identified if:

- the difference between quarterly location measurement and quarterly LRAA is > 30 µg/L and the LRAA is $ 40 µg/L for TTHM.

and/or

- the difference between quarterly location measurement and quarterly LRAA is > 25 µg/L and LRAA is $ 30 µg/L for HAA5.

All of the monitoring locations affected by high DBP are located in the area served by the Softwood plant or in the mixing zone. The city staff has reason to believe that a water quality change that has occurred in Softwood River caused the increase in DBPs.

Significant Excursion Evaluation Report Page 1	Report date: October 16th, 2004 Report prepared by: Robert Doe, P.E. System name: Elm City

1) When was the significant excursion sample(s) collected? What were the TTHM and HAA5 concentrations?

Location No.	# 5	# 6	# 7	# 8
Location description	Hardwood/Softwood Mix Zone – High TTHM	Hardwood/Softwood Mix Zone – High TTHM	Softwood plant – average residence time	Softwood plant – High HAA5
Sample collection date	Sept. 4th, 2004	Sept. 4th, 2004	Sept. 4th, 2004	Sept. 4th, 2004
Sample collection time	10 a.m.	2 p.m.	11 a.m.	3 p.m.
TTHM LRAA Concentration (ug/L)	55	66	50	76
TTHM Concentration (ug/L)	79	121	77	146
HAA5 LRAA Concentration (ug/L)		47	27	56
HAA5 Concentration (ug/L)		72	59	98

Note: Attach additional sheets if you observed more than four significant excursions during this round of sampling.

2) Where did the excursion(s) occur? Attach a schematic of your system, sketch your system in the space below, or have a schematic of your system available to review with your state at the time of your next sanitary survey. Indicate the location(s) of the significant excursion(s) on your schematic.

Location #5 – This site is in the downtown area and is located in the Hardwood/Softwood plants mixing zone.

Location #6 – This sample location is a faucet at a connection located in Weeping Willow - a zone of the distribution system that has been recently developed. This connection is located downstream from a chlorine booster station. Water in this area is generally a mix of water from the Hardwood and Softwood River Plants.

Location #7 – Represents average residence time of water leaving the Softwood Plant.

Location #8 – This sampling location is in an area that receives water from the Softwood Plant. Samples are collected at a hose bib near the first house on the cul-de-sac (which has 12 homes total).

For this example, these sample locations are illustrated in Figure F.1

3) Attach (or provide in the Supplemental Data Form) all available water quality data for the round of sampling in which the significant excursion occurred. At a minimum, include all TTHM and HAA5 results from the sampling period. You should also consider including pH, temperature, alkalinity, TOC, disinfectant residual, and any other data that you think would be useful.

   a) Were there any unusual circumstances associated with this round of sampling?

      Yes____ No_X__

      If yes, please explain.

   b) Were all analytical QA/QC measures met?

      Sample preservation Yes _X__ No____

      Sample holding time Yes _X__ No____

      Other ____________________

      ____

      ____

      If no, please explain.

4) Attach (or provide in the Supplemental Data Form) historical TTHM and HAA5 data for the location(s) at which the significant excursion(s) occurred. Provide at least three years of data, if available.

Significant Excursion Evaluation Report
Page 3

Report date: October 16th, 2004

5) What caused your excursion(s) to occur?

Sections A through F starting on page 4 can help you determine the possible cause(s) of your excursion. Please note there may be more than one factor which resulted in your excursion.

Section A: Source water quality change
Section B: Process upset at treatment plant
Section C: Planned change or maintenance activities at plant
Section D: Planned distribution system operations or maintenance activities
Section E: Unplanned events in distribution system

If you already suspect a cause, go directly to that section. If you read Sections A through E and are unable to determine a cause of your excursion, then complete Section F.

Consecutive systems should also contact their wholesaler to identify the cause(s) of the significant excursion(s).

6) List steps taken or planned to reduce DBP peak levels.

We are considering adjustments of the coagulation processes to improve TOC removal including: increasing the coagulant dose, evaluation of alternative coagulants, evaluation of coagulant aids, lowering the pH of coagulation, use of a pre-oxidant (permanganate or chlorine dioxide), and use of PAC.

A. Source Water Quality Changes

- Did any of the events listed below take place before the DBP excursion to cause TOC levels to increase?
  - Heavy rain fall
  - Flooding
  - Spring snow-melt/runoff
  - Significant decrease in rainfall or source flow
  - Algae bloom

- Did any of the events listed below take place before the DBP excursion to cause bromide levels to increase?
  - Significant decrease in rainfall or source flow
  - Brackish or seawater intrusion

- Did pH and/or alkalinity significantly change?

- If two or more supplies are used, was a greater portion of water drawn from the one with higher TOC?

- Was raw water stored for an unusually long period of time resulting in a significant increase in water temperature?

Conclusions:

Did source water quality changes cause or contribute to your significant excursion(s)?

Yes __X__ No ______

If yes, please explain:

The most probable cause of the DBP excursion noted during the September 2004 sampling even was a rapid increase of the organic matter concentration in the Softwood River. Following two days of heavy rainfall the TOC measured in the plant influent increased from 2.7 mg/L to 8.4 mg/L. At the same time, turbidity of the source water also increased from 5 ntu to a maximum of 98 ntu. The coagulant (ferric chloride) dose was increased from 20 mg/L to 75 mg/L to match water quality changes. For the duration of this high turbidity/high NOM event, the pH of coagulation was maintained between 61. and 6.3. The higher coagulant dose prevented any significant increases of turbidity in the settled water, but the concentration of TOC in the plant effluent increased from 1.8 mg/L to 3.8 mg/L. Jar testing conducted at the time of the event indicated that a further increase of the coagulant dose (dosages up to 120 mg/L were tested) would have not significantly improved TOC removal under the pH conditions presently used to conduct the coagulation process.

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Significant Excursion Evaluation Report
Page 5

Report date: October 16th, 2004

B. Process Upset at Treatment Plant

- Was raw water stored for an unusually long time, providing additional contact time for DBP formation after prechlorination?

- Were there changes in coagulation practices?
  - Were there any changes or malfunctions of the coagulation process in the days leading to the excursion?
  - Were the coagulant dose and pH properly adjusted for incoming source water conditions?

- Were there changes in chlorination practices?
  - Were there any changes in chlorine dose at any location in the plant?
  - Were there changes in plant flow that may have resulted in longer than normal residence time at any location in the plant?
  - Did the pH change at the point of chlorine addition?

- Were there changes in settling practices?
  - Was there excess sludge build-up in the settling basin that may have carried over to the point of disinfectant addition?
  - Was there any disruption in the sludge blanket that may have resulted in carryover to the point of disinfection?

- Were there changes in filtration practices?
  - Have filter run times been changed to meet raw water quality changes?
  - Were there any spikes in individual filter effluent turbidity (which may indicate particulate or colloidal TOC breakthrough) in the days leading to the excursion?
  - Did chlorinated water sit in the filter for an extended period of time?
  - Were all filters run in a filter-to-waste mode during initial filter ripening?
  - Were any filters operated beyond their normal filter run time?
  - If GAC filters are used: Is it possible the adsorptive capacity of the GAC bed was reached before reactivation occurred?
  - If biological filtration is used: Were there any process upsets that may have resulted in breakthrough of TOC (particularly biodegradable TOC)?

- Were there changes in plant flow that may have resulted in an unusually high residence time in the clearwell on the days prior to the excursion?
  - For example, a temporary plant shutdown.

Continued on next page

Significant Excursion Evaluation Report

Page 6

Report date: October 16th, 2004

B. Process Upset at Treatment Plant (Continued)

Conclusions:

Did a process upset in the treatment plant cause or contribute to your significant excursion(s)?

Yes____ No __X__

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Significant Excursion Evaluation Report
Page 7

Report date: October 16th, 2004

C. Planned Change or Maintenance Activities for the Treatment Plant

- Was there a recent change (or addition) of pre-oxidant?
- Was there any maintenance in the basin that may have stirred sludge from the bottom of the basin and caused it to carry over to the point of disinfectant addition?
- Did you change the type or manufacturer of the coagulant?
- Were there any changes in disinfection practices in the days prior to the excursion?
  - For example, a switch from chloramines to free chlorine for burnout period.
  - Discontinuation of ozone which forms very little TTHM.
- Was a filter(s) taken off-line for an extended period of time that caused the other filters to operate near maximum design capacity and creating the conditions for possible breakthrough?
- Were any pumps shut down for maintenance, leading to changes in flow patterns or hydraulic surges?

Conclusions:

Did a planned maintenance or operational activity in the treatment plant cause or contribute to your significant excursion(s)?

Yes_____ No __X__

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

D. Planned Distribution System Operations or Maintenance Activities

- Was a tank drained for cleaning or other maintenance?
  - Was the tank drained to waste or to the distribution system?
  - Was a larger volume than normal drained to the distribution system?

- If booster disinfection is used, was the booster disinfectant dose higher than the normal booster disinfectant dose for that season?

- Were there any system maintenance activities in the days prior to DBP excursion? Including:
  - Repairing mains or installing new mains
  - Closure of valves to isolate sections of pipes

- Were the pipes flushed properly or were the appropriate valves re-opened after work was completed?

- Did any pump or pipeline maintenance occur that would have changed the flow pattern in the area the sample was drawn from?
  - Change in flow can cause water in stagnant areas to be drawn into another area.

- Did any pipeline replacement occur?
  - Disinfecting piping in contact with drinking water could result in a high concentration of chlorine entering the distribution system and thus increase DBPs.

Conclusions:

Did a planned distribution system maintenance or operational activity cause or contribute to your significant excursion(s)?

Yes _____ No __X__

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Report date: October 16^{th}, 2004

E. Unplanned Distribution System Events

- Were there increases in demand that caused older water in storage tanks to be drawn into the system?
  - Were there any major fire events?
  - Did one or more storage tank have greater than average drawdown preceding the time of DBP peak excursion?

- Were there decreases in demand that resulted in longer than normal system residence times?
  - Were there any large customers off-line?

- Did any main breaks occur causing changes in flow patterns in the influence area of the sample location?

- If you collect water temperature inside storage tanks, was the temperature inside the tank higher than normal for the season?

- Were any storage tanks hydraulically locked out of the system for an extended period and then used preceding the time of DBP peak excursion?

- Did changes in overall water demand cause a change in water demand patterns in the vicinity of dead ends and/or stagnant zones in the system?

- Were there large variations in localized system pressures that were different from the normal pressure range that could have caused a change in water demand patterns in the vicinity of dead ends and/or stagnant zones in the system?

Conclusions:

Did an unplanned distribution system maintenance or operational activity cause or contribute to your significant excursion(s)?

Yes____ No __X__

If yes, please explain:

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Report date: October 16th, 2004

F. If you were unable to identify the cause of your significant excursion(s) after reviewing Sections A through E, are you able to identify another potential cause of your increase in DBP concentrations? Explain.

Note: *If you are unable to determine the cause of your excursion you may wish to consider:*

- More frequent raw water temperature monitoring.
- More frequent raw water TOC monitoring.
- Increased disinfectant residual monitoring in the distribution system.
- Tracer studies to characterize distribution system water age.
- Development of a hydraulic model to characterize the distribution system.

Attach all supporting operational or other data which led you to conclude this was the cause of your excursion(s) or make sure this data is available during your sanitary survey.

Supplemental Data Form for the Significant Excursion Evaluation Report

Report date: October 16th, 2004

Report prepared by: Robert Doe, P.E.

System name: Elm City

1) Water quality data from significant excursion sampling period.

Location No.	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**
Location Name								
TTHM (ug/L)	63	72	81	78	**79**	**121**	**77**	**146**
HAA5 (ug/L)	52	39	51	66	58	**72**	**59**	**98**
Free Chlorine (mg/L)	1.8	1.3	NA	NA	NA	1.1	NA	0.8
Total Chlorine (mg/L)	2.1	1.8	NA	NA	NA	1.8	NA	1.2
pH	7.9	8.0	8.3	8.1	7.8	8.3	7.5	8.2

Data relevant to peak excursions are **bold and underlined**.

2) Supplemental data from each treatment facility:

Plant #1: Hardwood Plant
Raw Water Temperature: NA
Plant Effluent Water Temperature: 20 °C

Raw Water TOC: 2.2 mg/L (Avg. <2.0mg/L)

Other Data:

Plant #2: Softwood Plant
Raw Water Temperature: NA
Plant Effluent Water Temperature: 20 °C

Raw Water TOC: 3.8 mg/L (Avg.<2.0mg/L)

Other Data: Inf. turb. 98 ntu (Avg. <20 ntu)

3) Historical TTHM and HAA5 data at significant excursion sampling locations.

TTHM Data (ug/L)

Monitoring Location	# 5	# 6	# 7	# 8
Date - 1999	43	58	45	49
Date - 2000	51	49	56	64
Date - 2001	46	69	41	69
Date - 2002	48	61	73	66
Date - 2003	34	44	53	79
Avg. 99-03	44	56	54	65

HAA5 Data (ug/L)

Monitoring Location	# 6	# 7	# 8	#
Date - 1999	57	52	56	
Date - 2000	48	39	47	
Date - 2001	45	48	33	
Date - 2002	51	56	34	
Date - 2003	45	31	43	
Avg. 99-03	49	45	43	

Attach additional sheets if necessary